

■ ROBOTICS ■ MICROCONTROLLERS ■ COMPUTER CONTROL ■ SPACE

NUTS AND VOLTS

NUTS AND VOLTS

EVERYTHING FOR ELECTRONICS

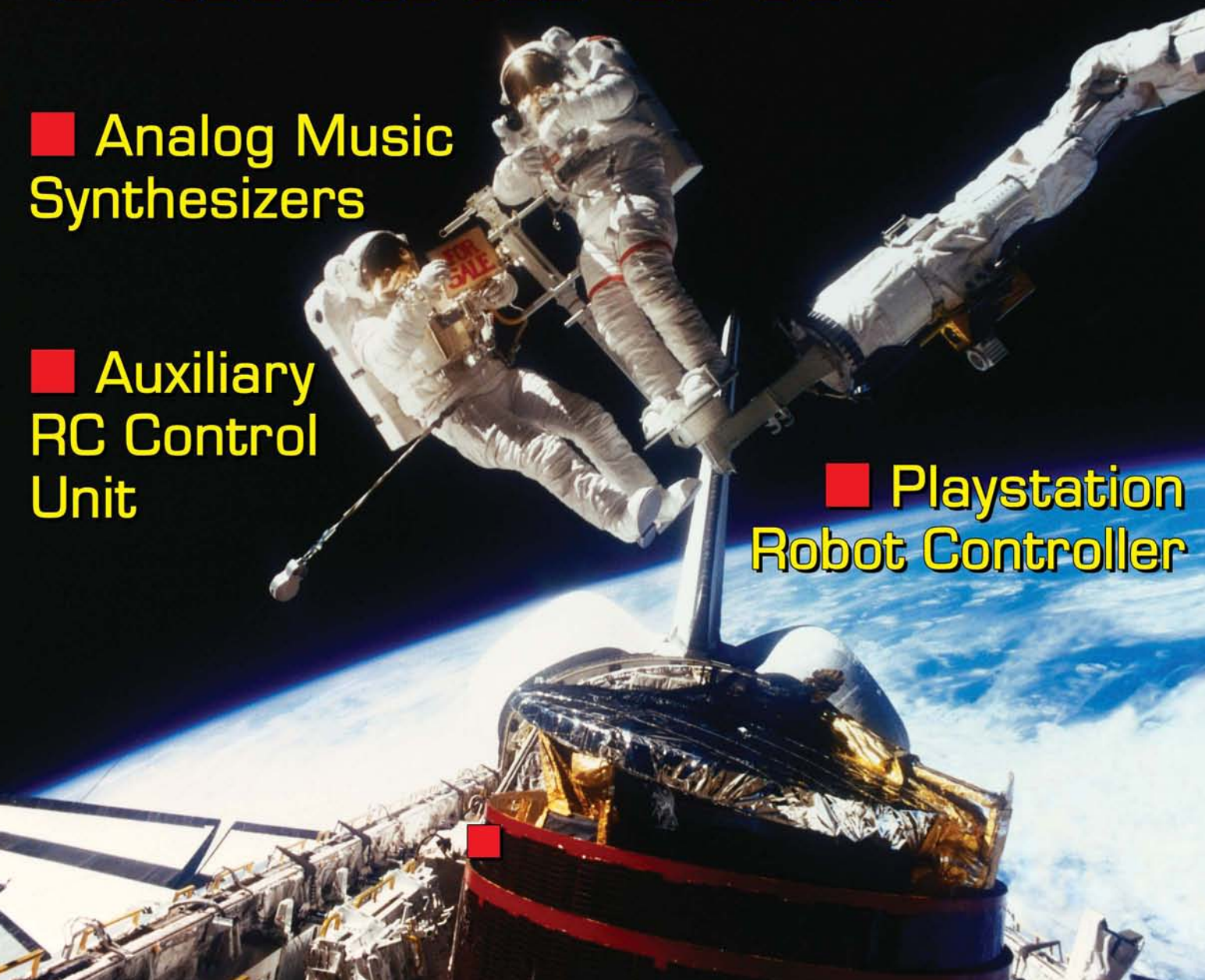
BUILD YOUR OWN

CanadArm

■ Analog Music Synthesizers

■ Auxiliary RC Control Unit

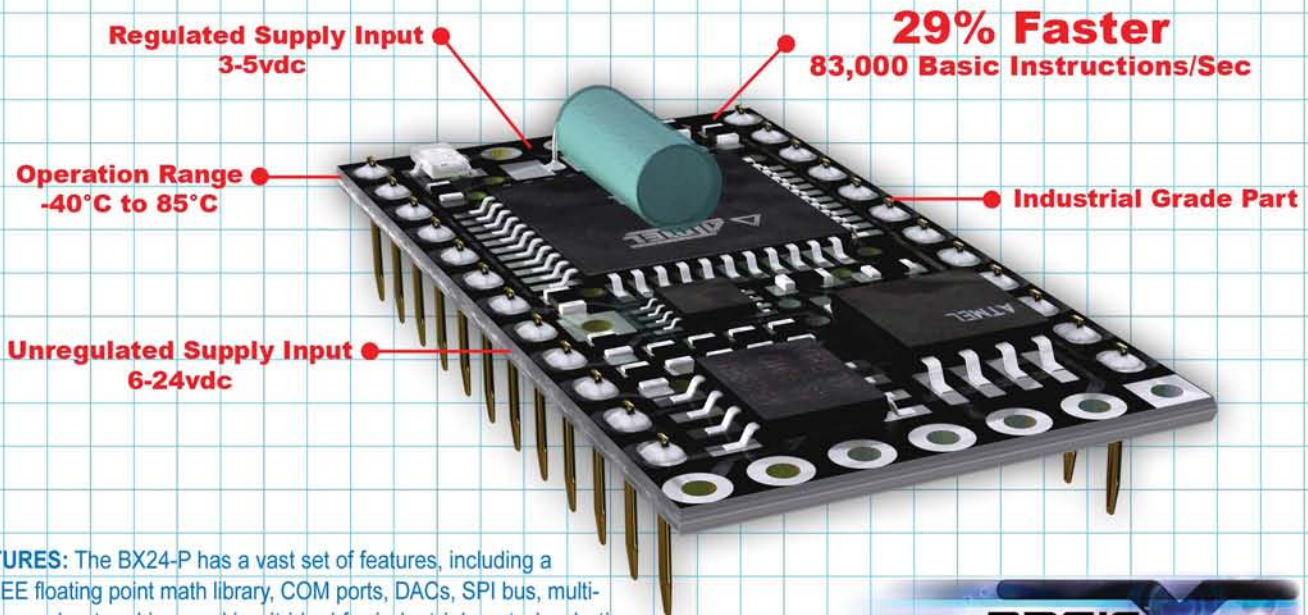
■ Playstation Robot Controller



Announcing the BasicX - BX24-P

The *fastest* Basic programmable microcontroller...

Just Got BETTER for the same price \$49.95



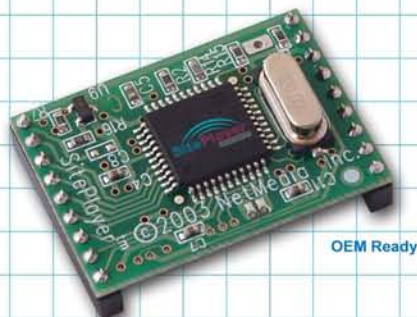
FEATURES: The BX24-P has a vast set of features, including a full IEEE floating point math library, COM ports, DACs, SPI bus, multi-tasking and networking, making it ideal for industrial control, robotics, automated testing equipment and home automation. BX24-P is able to monitor and control all your switches, timers, motors, sensors, relays, and more. Measuring just 1.25" X .75", OEMs can easily see the value of this little powerhouse.



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SPT1 – SitePlayer Telnet™ OEM module
ONLY \$29.95

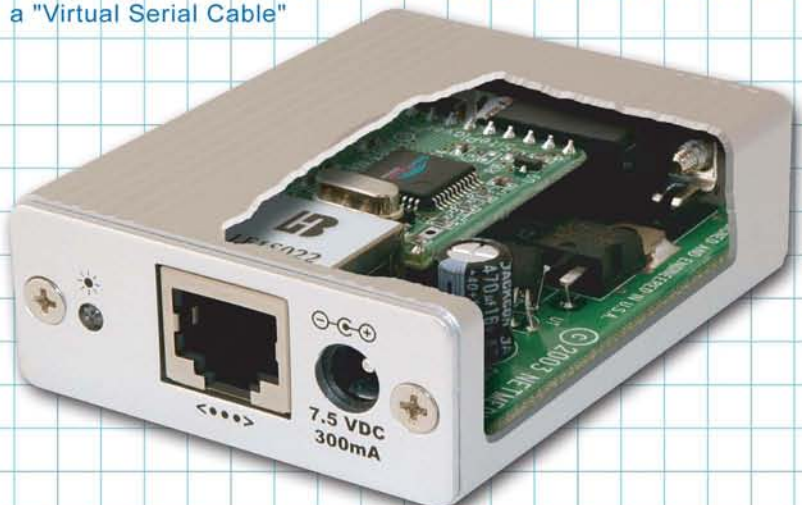


Features - 10BaseT, ARP, UDP, TCP/IP, DHCP, Link Local, Bonjour, ICMP Ping, HTTP, Telnet, Daytime protocol, Discard protocol, 4 IP addresses, Serial AT command mode for external processor control of Ethernet sessions.

Enable your serial devices to communicate across Ethernet

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SPEED

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SOFTWARE

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POINT
MATH

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SPACE

PWM

BUFFERED
RS232

REAL
ADC

ADVANCED
BASIC

LADDER
LOGIC



PLC / Embedded controller

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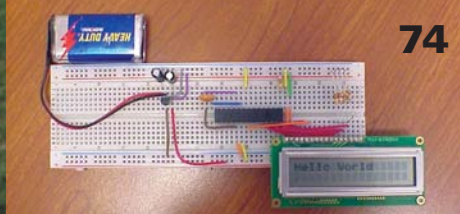
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NUTS AND VOLTS

JANUARY 2006

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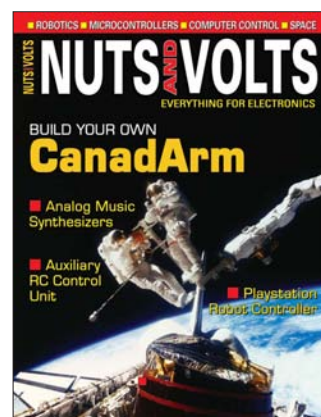
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Good news! It isn't that difficult and it doesn't have to cost a bunch of money to get started with microcontrollers.

■ By Chuck Hellebuyck

ON THE COVER ...

The "Blame it on CanadArm" near space version of the real thing. Check out the Near Space column starting on Page 84.



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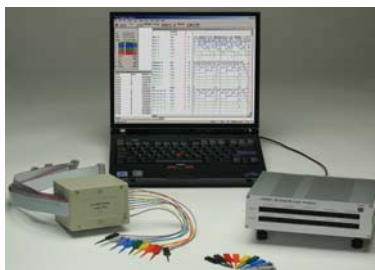
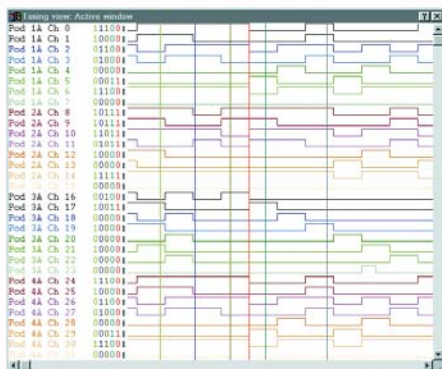


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OUT WITH TRENCHES

I just wanted to tell you how much I have enjoyed your magazine. In fact, I am building the Ultimate Utility Meter now.

One thing that I am a little disappointed in is, that I look at you being my hobby magazine. The section "In The Trenches" is out of place. I have enough trade magazines with that information. I would like to see you stay away from that aspect and be there for the hobbyist and the professional that needs to get away from work and learn new skills. Thank you and keep up the good articles.

Jack Boswell

WRITER WRITES BACK

I authored the article "I Love my Heils!" published in the October issue of *Nuts & Volts* and would like to respond to your reader feedback on my article. The information in the article stating that Dr. Oskar Heil is the inventor of the field effect transistor and that he patented it in 1934 is correct. Please see <http://en.wikipedia.org/wiki/Transistor>. The paper demonstration is a typical

method of demonstrating wave phenomena, and I'm sorry that your reader did not understand the concepts, but it is correct. Also, cost is always a primary driver for products, and a simple cone loudspeaker is the least expensive audio transducer and is acceptable to most people, so dominates the market, even though the Heil Air Motion Transformer provides superior performance.

It's great that *Nuts & Volts* has such passionate readers, and I'm glad that my article received so much attention!

Dennis Eichenberg

LOVE US

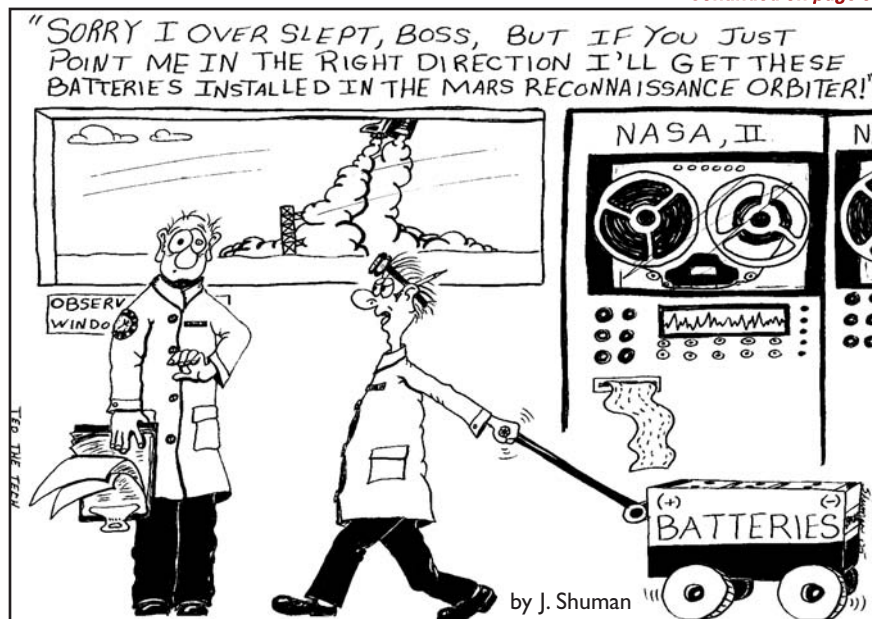
I'm a mail subscriber and I've just got my November *N&V* issue. I think it's amazing how much you have improved the whole magazine design. Congratulations to all that people over there. My favorite magazine is now even much better.

J.M. Gomez

LOVE US NOT

In reference to the Reader Feedback "Format Folly" in the Dec. issue, I fully agree with Len Taddei. The new format is a mess!!! I don't like it!!!

Continued on page 53



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P.O. Box 15277

North Hollywood, CA 91615

FOUNDER/ASSOCIATE PUBLISHER

Jack Lemieux

PUBLISHER

Larry Lemieux

publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF SALES/MARKETING

Robin Lemieux

display@nutsvolts.com

CONTRIBUTING EDITORS

Gerard Fonte

Jeff Eckert

Paul Weijers

J. Ronald Eyton

James Antonakos

Paul Verhage

TJ Byers

Jon Williams

Gamal Labib

Christopher McCauley

Thomas Henry

Chuck Hellebuyck

CIRCULATION DIRECTOR

Tracy Kerley

subscribe@nutsvolts.com

SHOW COORDINATOR

Audrey Lemieux

WEB CONTENT/NV STORE

Michael Kaudze

sales@nutsvolts.com

PRODUCTION/GRAPHICS

Shannon Lemieux

Michele Durant

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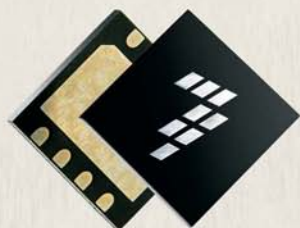
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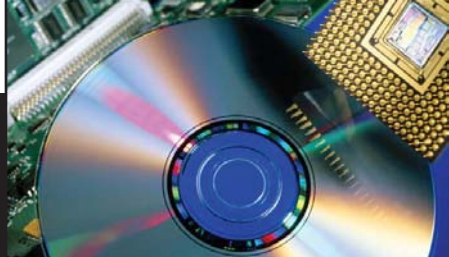


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TECH KNOWLEDGEY 2006

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

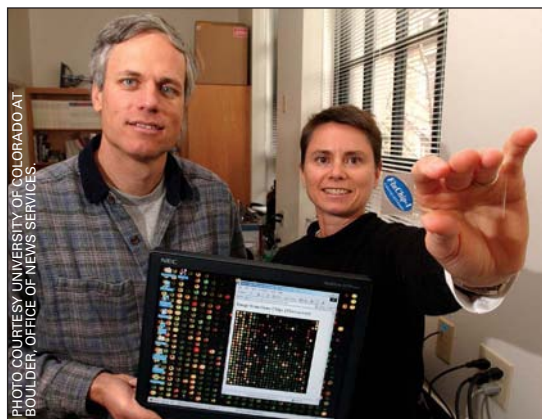
ADVANCED TECHNOLOGIES

INVENTION USES LASER SCANNER FOR VIRUS ID

Perhaps just in time for the looming bird flu pandemic, a device has been developed at the University of Colorado at Boulder (www.colorado.edu) that can determine the genetic signatures of specific influenza strains from patient samples quickly. Tests by the Centers for Disease Control and Prevention have verified that the CU-Boulder Flu Chip can determine the genetic makeup of types and subtypes of the flu virus in about 11 hours.

The chip fits on a microscope slide and contains an array of microscopic spots, each of which is about 0.001 inches in diameter. Genetic bits of information that are complimentary to known individual influenza strains are "spotted" robotically in an array such that each row of three spots contains a specific sequence of "capture" DNA. The microarray is then immersed in a wash of influenza gene fragments obtained from the fluid of an infected individual. RNA fragments from the infected fluid bind to specific DNA segments on the microarray like a key in a lock, indicating both a match and that the virus signature is present. The

■ Professors Robert Kuchta and Kathy Rowlen display a scanner and the Flu Chip.



captured RNA is then labeled with another complimentary sequence that also contains a fluorescent dye, and such "hits" light up when the chip is inserted into a laser scanner.

The Flu Chip also should be able to recognize mutations that might occur in avian flu H5N1, which has been spreading rapidly from bird to bird in Asia, Russia, and parts of Europe. The ultimate goal is to shrink the concept down to a cheap, hand-held device that can be mass produced and taken into remote locations where medical labs don't exist.

VENUS PROBE ON ITS WAY

By the time you read this, the European Space Agency's Venus Express should have already left a launch pad in Kazakhstan, having been lifted into space by a Soyuz rocket, and be on its way to Earth's "evil twin," Venus. The spacecraft, carrying seven scientific instruments for studying the planet, is a honeycombed aluminium panel box within which all the systems and the payload are fixed. It measures 1.5 x 1.8 x 1.4 m, excluding the solar panels, and weighs in at 1,240 kg, including 93 kg of payload and 570 kg of fuel. With the solar panels extended, the unit measures about 8 m across.

The basic mission, which comes at a cost of about 220 million euros, is to make the first global examination of the Venusian atmosphere, which is very hot and dense and appears to be completely different from the one around Earth. Existing meteorological models fail to predict the behavior of Venus's thicker blanket of gases.

In particular, the probe will investigate (1) the choking greenhouse effect on Venus, (2)



■ Artist's impression of Venus Express orbiting Venus.

the hurricane force winds that permanently encircle the planet, (3) why Venus rotates backward and so slowly (just one revolution every 243 Earth days), (4) the mysterious ultraviolet absorption features at an altitude of about 80 km (5), the planet's mysteriously weak magnetic field, and (6) the way particles from the sun interact with the upper atmosphere. Slated to arrive near the end of April, Venus Express' mission will last for about 1,000 Earth days, after which it will run out of fuel. For details, and to keep an eye on its progress, visit www.esa.int

QUANTUM PHYSICS DISPROVEN?

Perhaps even farther out than Venus is a concept from Black Light Power, Inc., of Cranbury, NJ. The company claims to have developed a working prototype of a power source that unleashes substantial latent energy in hydrogen atoms, allowing it to generate as much as 1,000 times as much heat as conventional fuels. The process involves creating a new form of hydrogen atom, called the "hydrino," in a process that causes the atom's elec-

tron to move to a lower orbit around the proton. This generates power in the form of heat, light, and plasma. The energy released from the process is claimed to be hundreds of times greater than that needed to start it, and the by-product would constitute an entirely new class of chemistry referred to as hydrino hydride compounds. The only problem is that the rules of quantum mechanics tell us that electrons' orbits are strictly defined and cannot be changed, thus indicating that the Black Light process is impossible.

Is this a breakthrough or just another incarnation of room-temperature fusion? Time will tell. In the meantime, there are some very interesting graphics and animations on the company's website, so you might want to visit www.blacklightpower.com and make your own assessment.

COMPUTERS AND NETWORKING

NEW SUPERCOMPUTER PERFORMANCE RECORDS

Late last year, the National Nuclear Security Administration (NNSA) officially dedicated two new supercomputers to ensure that the US nuclear weapons stockpile remains safe and reliable without nuclear testing. The IBM machines are housed at Lawrence Livermore National Laboratory (LLNL; www.llnl.gov) and are the culmination of a 10-year campaign to use supercomputers to run three-dimensional codes at lightning-fast speeds to achieve much of the nuclear weapons analysis that was formerly accomplished by underground nuclear testing. One of the machines, BlueGene/L, performed a record 280.6 trillion operations per

second (teraflops) on the industry standard LINPACK benchmark. Purple, the other half of the most powerful supercomputing pair on Earth, is capable of 100 teraflops as it conducts simulations of a complete nuclear weapons performance. In a recent demonstration of its work capability, BlueGene/L ran a record-setting materials science application at 101.5 teraflops sustained over seven hours on the machine's 131,072 processors. Working together, the machines can generate an astounding half a petaflop, or 0.5 quadrillion operations per second.

BlueGene/L will move into classified operation in February to address critical problems of materials aging. The machine is primarily intended for stockpile science molecular dynamics and turbulence calculations. Purple consists of 94 teraflop classified and six teraflop unclassified environments. The machine's architecture, with large memory, powerful processors, and massive network bandwidth, is designed for running newly developed 3D weapons codes needed to simulate complete nuclear weapons performance. The insights and data gained from materials aging calculations to be run on BlueGene/L will be used for the creation of improved models designated for future full weapons performance simulations on Purple.

IF YOU THINK CABLE STINKS NOW ...

It may sound strange, but Nethercomm Corp. (www.nethercomm.com) has come up with a technology that may soon bring you television, telephone, and Internet communications through existing natural gas pipelines. The technology has been dubbed, appropriately enough, broadband-in-gas (BiG). While the company's press release didn't provide the specifics about

how it is done, it is known that two approaches have been demonstrated by researchers at the University of Missouri-Rolla over the past few years.

One is to use the pipeline as a microwave waveguide, and the other is to use the metal pipe as a conductor; both methods were shown to be feasible. According to Nethercomm, their technology "requires no modification to existing natural gas distribution infrastructures and can carry enormous amounts of data by simply making use of the entire spectrum buried within the existing natural gas pipelines. The technology delivers connectivity over the last mile of broadband networks without interference or degradation of other wireless transmissions.

By not consuming or sharing costly spectrum, and not requiring installation of last mile cable or fiber, Nethercomm is prepared to make broadband substantially more affordable while increasing end-user bandwidth to unprecedented levels." And if a report from West Technology Research Solutions (www.westtechresearch.com) is correct, BiG will be connected to as many as 18 million homes by 2010. This is theoretically possible, given that something like 70 percent of homes and 35 percent of businesses in the US have access to gas lines. Weird concept perhaps, but anything that can provide an alternative to your local monopoly cable company can't be all bad.

CIRCUITS AND DEVICES

SOLAR-POWERED SENSOR ELIMINATES BATTERIES

EnOcean (www.enocean.com), a German company specializing in energy-harvesting wireless technologies, has introduced the STM250 solar-powered radio frequency (RF) magnet-contact sensor. Its claim to fame is that it eliminates a major deficiency of wireless security systems: their dependence on batteries. By doing away with the burdens of battery monitoring and replacement, the new magnet contact theoretically can operate for years without mainte-



PHOTO COURTESY OF LLNL, BY JOSEPH MARTINEZ.

■ BlueGene/L, with its distinctive eight slanted-front cabinets, hits 280.6 trillion operations per second.



PHOTO COURTESY OF ENOCEAN GMBH.

■ EnOcean's STM250 sensor is designed for wireless security systems.

nance, using only ambient indoor or outdoor light. The amount of light typically available in homes or offices is sufficient to both operate STM250 continuously and to store energy for up to six days' use in total darkness. The unit's embedded RF transmitter will send a signal across 300 m outdoors and 30 m indoors, through walls. Because the entire signal transmission is completed in about 1/1,000 of a second, the power drain is minimal.

The sensor can be used either as a ready-to-install switch for security system contractors or as an OEM-level product for integration into doors and windows. It can even be permanently embedded inside impossible-to-reach places, such as between panes of window glass. STM250s are available in OEM quantities for about \$30 each.

DOUBLE-ILLUMINATED ROCKER SWITCH

■ If you need to employ rocker switches in your next project, NKK Switches

INDUSTRY AND THE PROFESSION MICROSOFT MOVES INTO VOIP BUSINESS

In November, Microsoft Corp. (www.microsoft.com) announced it has agreed to acquire media-streams.com AG, a Zurich-based company that develops communications applications based on voice over Internet protocol (VoIP) technology. Microsoft plans to apply media-streams.com's technology, employees, and intellectual property to create a unified communications package that brings together various modes of communication (e-mail, instant messaging, short message service, voice/telephony, and audio, video, and Web conferencing).

The media-streams.com technology will help Microsoft develop an improved, integrated VoIP product based on the Microsoft® Office Real-Time Collaboration platform, Microsoft Office Live Communications Server. In the announcement, a Microsoft representative noted, "With this acquisition, Microsoft aims to extend VoIP to communications solutions to improve productivity and business processes, creating new opportunities for Microsoft Real-Time Collaboration customers and partners."

COMPANY BUYS CELL PHONES

■ If you're thinking about tossing away the old cell phone, wait. CellForCash.com has bought more than 200,000 of them since it started up in 2002, and you just might be able to turn yours into cash. The company pays you cash, pays the shipping, and then recycles and resells the units all over the world, currently to the tune of 75,000 units per month. To find out how much your clunker is worth, just visit the site.

(www.nkkswitches.com) has introduced a somewhat nifty new design, the LW series. The snap-in mount, rocker devices are double pole and available in many circuit options, including maintained and momentary action. They are rated at a resistive load of 10A @ 125 VAC, 6A @ 250 VAC, or 6A @ 30

VDC. The inductive load rating is 5A @ 125 VAC. While nonilluminated versions are available, the more interesting ones offer dual-faced illumination.

You can create various lighting effects by choosing to use either white or clear rocker caps, with multiple colored filters or lamp covers. In addition, different colors can be specified on each side of the rocker. Available with either incandescent lamps in several voltages or neon bulbs, the light sources operate independently. Optional accessories include a decorative bezel, available in several different colors. **NV**

■ NKK's LW series switches feature dual lamps that operate independently.

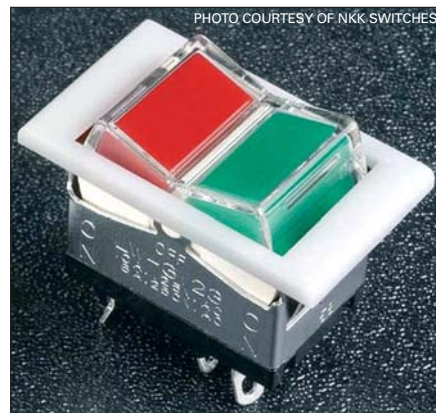


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- 3.7mm Flat Pin-Hole Lens, 0.05 Lux

\$69.95

KPC-S20CP3

- 1/4" Color Micro-Cased Camera
- 380 TVL of Resolution
- 3.7mm Flat Pin-Hole Lens, 1.0 Lux

\$89.95

KPC-S20PHEX3

- 1/3" B/W Micro-Cased Camera
- **600 TVL of Super High Resolution**
- 3.7mm Flat Pin-Hole Lens, 0.0003 Lux
- ExView Sony CCD Chip

\$119.95



KPC-S20B

- 1/3" B/W Micro Cased Camera
- 420 TVL of High Resolution
- 3.6mm Lens with 0.05Lux

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KPC-S20CB

- 1/4" Color Micro Cased Camera
- 380 TVL of Resolution
- 3.6mm Lens with 1.0Lux

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WHAT'S UP:

Kick off the new year with a potpourri of circuits.

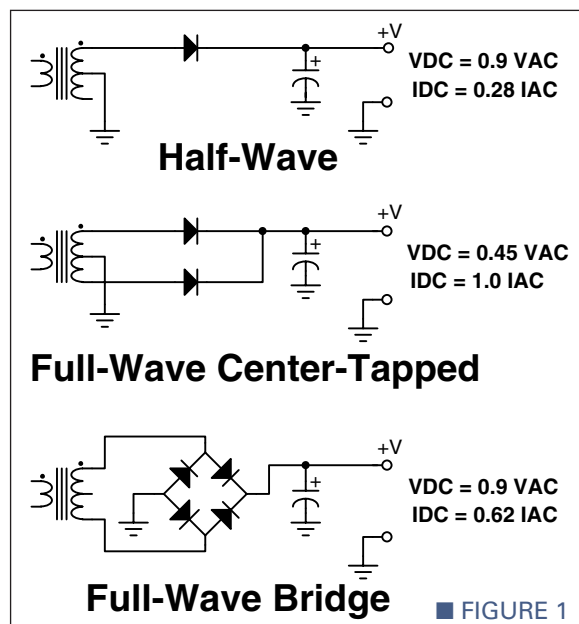
■ WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments or suggestions.

You can reach me at: TJBYERS@aol.com

- ✓ UV photometer, a clock heater, and a vacuum tube filament supply.
- ✓ Solutions for the deceased MM5369 clock chip and a new 15-minute timer.
- ✓ Plus, a power transformer tutorial and how to prevent PA feedback.



into saturation and ceases to function properly. This is especially important when the transformer has more than one secondary winding. The resistance of the primary and secondary windings also influences the amount of current a transformer will handle because increased resistance and higher current makes heat — heat that must be dissipated. Your particular transformer has a rating of 240VA which means it will deliver 10 amps at 24 volts.

But I don't think this is the answer you're looking for, because I assume you want to turn this AC into DC. The DC current output is determined by the configuration of the rectifier circuit — of which there are three:

1. Half-wave (single diode)
2. Full-wave center-tapped (two diodes)
3. Full-wave bridge (four diodes)

Refer to Figure 1 for the following discussion. The advantage of half-wave rectification is in its simplicity — one diode and a capacitor. They are generally viable only for power supplies of one-half watt or less, and require more filtering than full-wave rectification.

The full-wave center-tapped rectifier uses only half the transformer sec-

ondary at a time — which results in an output voltage that is one-half (0.45, to be exact) the full voltage across the secondary, but takes advantage of the full 10 amps your transformer has to offer. The full-wave bridge rectifier outputs a voltage that is 0.9 percent that of the transformer voltage, but can only use 0.62 percent of the transformer's current. To achieve the desired DC load current, the transformer current should be 1.6 times higher. For example, to get 10 amps of DC, you need to have 16 amps available to the rectifiers.

Why? Because of the surge current required by the filtering capacitor. Transformers are not ideal and have an internal impedance or "regulation" characteristic. As the load increases, the output voltage decreases. Consequently, the transformer current must be sufficient enough to overcome the extra current imposed by the charging capacitor. A way to eliminate this requirement is to insert a filter choke in series with the line to the filter cap. Doing this will let you use the full potential of the transformer's current rating — at the cost of an extra inductor and added space.

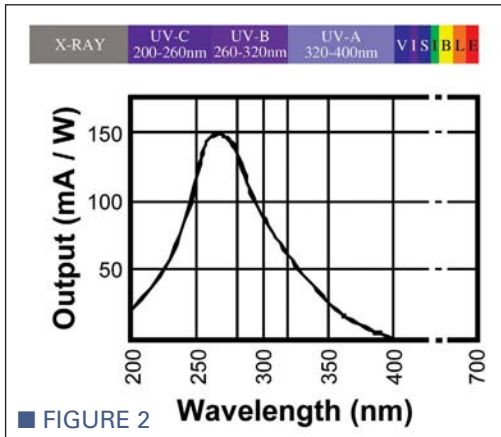
TRANSFORMER RATINGS

Q I have a power transformer with the following specifications: 24VCT (12 - 0 - 12) 10A. If the center-tap terminal is not used — and we used it as a 24-volt transformer — then will its rating remain at 10A or will it be half of that value (5A)?
B.Bill

A Transformers are rated in volt amps (VA). It defines the limit of the magnetizing field inside the transformer. If this limit is exceeded, the transformer goes

UV-C MONITOR

Q Could you suggest a circuit for measuring the UV output of a mercury vapor fluorescent type bulb? This type of bulb is used



for germicidal lamps, as well as photo resists for printed circuits. My particular application is for aquarium purification. After so many hours of use, the UV falls off and there is no indication of bulb degradation until fish start getting sick. The bulbs are very expensive — typically \$45 — and the end-of-life varies from one to another. The ability to monitor the UV output would save lives and money.

Charles Forman

A These lamps emit UV in the 200 nm to 300 nm range — that portion of the UV spectrum called UV-C. Also known as “short-wave” UV, this spectrum includes the target germicidal wavelength of 254 nm. An optical sensor sensitive to this wavelength — typically a PIN diode — is expensive to fabricate and runs \$20 and more. Fortunately, Digi-Key (800-344-4539; www.digikey.com) stocks the PDU-S101 from Advanced Photonics (\$20.17) that matches the UV-C spectrum to a tee (Figure 2). It comes in a rugged TO-46 hermetically sealed metal can with a UV transmitting window.

PIN photodiodes are current generators, where the output current is a linear function of light intensity. The brighter the light, the greater the current. Because it's easier to monitor voltage than current, the first thing we'll do is convert the current to a voltage using a simple op-amp. The second op-amp in Figure 3 is a voltage follower that buffers the current/voltage converter and prevents loading of the voltage converter. The output of the UV lamp can now be monitored using a simple voltmeter. A single nine-volt battery will power

the photometer for about a year if you power up the instrument only as needed. For 24/7 monitoring, you'll need a 78L09 regulated power supply.

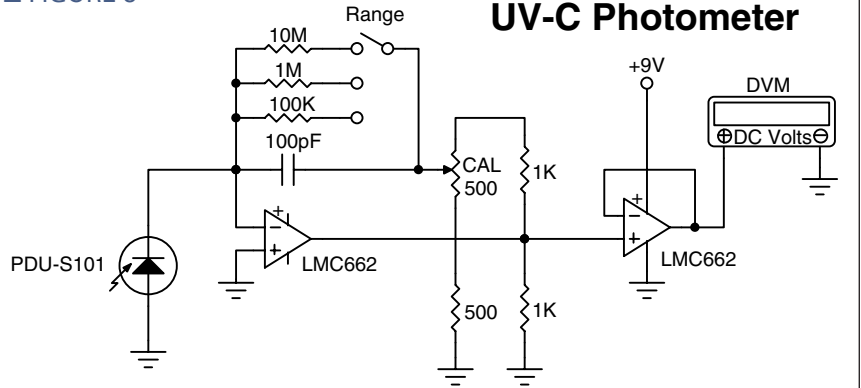
The Range switch is used to give a reading on the voltmeter; the 10M position is the most sensitive with the 100K position the least sensitive. Once a suitable range is found, use the CAL pot to obtain a voltmeter reading that makes sense to you. For example, if you calibrate the output for one volt with a fresh lamp, then a reading of 0.5 volts means the lamp has lost half its light output. You don't have to physically mount the photodiode next to the UV lamp — in fact, I warn against it. Instead, I'd use an optical fiber to channel the light from the lamp to the photodiode. Just make sure it's UV rated, otherwise your signal will be lost. Shielding the photodiode from ambient light would also be a smart move; black shrink wrap tubing is a good solution.

15 MINUTES, AGAIN AND AGAIN

Q I am looking for a 15-minute timer, but can't find what I want. I need a timer that's powered from a nine-volt source and toggles a relay for 15 minutes on and 15 minutes off. I've looked all over the Internet and can't find one. Can you help?

via Internet

■ FIGURE 3

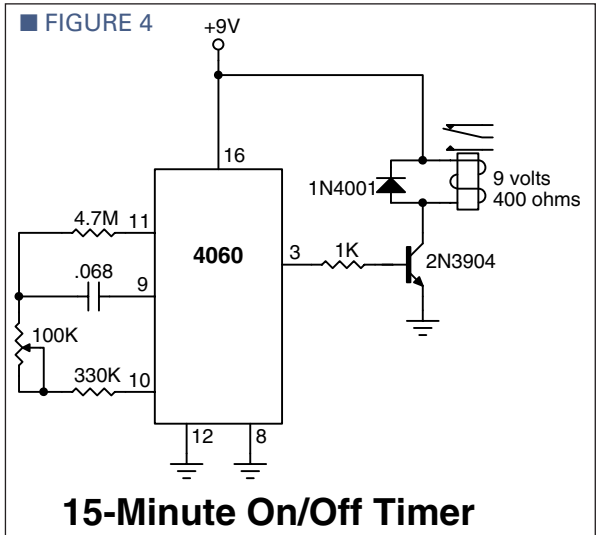


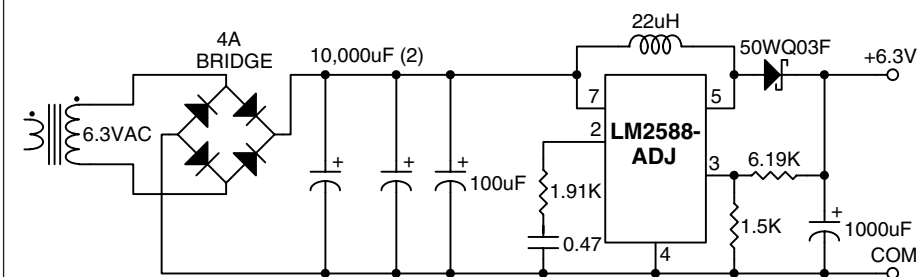
A This is a common request that I've addressed in past columns (e.g., May 2004), but one that's too frequent to ignore. So here is this year's take on the 15-minute timer. This time, I've replaced the analog timers with a 4060 ripple counter (Figure 4). The 4060 includes an RC oscillator whose frequency is set by two resistors and a single capacitor. (You may recognize this design from past columns, where I use two NAND gates to create a square-wave oscillator.) When the oscillator's frequency is 18.2 Hz, the Q14 output (pin 3) will toggle on and off every 15 minutes; the 100K pot fine-tunes the timer.

TUBE AMP POWER REGULATION

Q I'm looking to eliminate/minimize fluctuations in critical voltages in a guitar tube amp. The particular amp has

■ FIGURE 4





■ FIGURE 5

6.3 Volts DC, 3A

two EL34 power tubes and utilizes a solid-state rectifier; the output of the rectifier is 430 volts. My AC mains can fluctuate substantially, being 121 VAC one day and 127 VAC the next, and I have noticed that plate and bias voltages change 10 volts at the plates and one volt at the grid bias — depending on the day — which can result in several watts output variation. Is there a simple way to either regulate the AC supply into a power transformer or regulate the DC output from the rectifier?

Alan Mihalko

A A Sola ferroresonant transformer can regulate the AC input — kinda. Basically, it provides a constant output voltage using a saturated core transformer. Unfortunately, this arrangement “flattens” the top of the sine wave so it more closely resembles a square wave. Being a tube guy myself, I find that the temperature (voltage) on the filament has more influence on the output power than the plate voltage.

I would change the AC filament voltage into DC (which reduces hum), then regulate the DC voltage using a

step-up switching regulator — like the LM2588. The EL34 (a.k.a., 6CA7) needs about 1.5 amp filament current at 6.3 VAC. Toss in an ECC83 (12AX7) preamp/driver, and the total load is a tad over three amps. For this design, I went to the National Semiconductor website (www.national.com), selected Power under WEBENCH Design Tools, and entered the operating parameters. What popped up on the screen was the circuit in Figure 5.

The design also includes a Bill of Materials (BOM) that lists parts by manufacturer number and specs. Circuit simulation and analysis are also part of the design features, and an optional custom prototype kit for some designs. If you haven’t taken advantage of this National Semiconductor service, there’s no better time than the present.

ALL-PURPOSE THERMOSTAT

Q I am in the process of constructing a clock using an old master clock movement and pendulum. To keep the clock

on time, I need to compensate for temperature variations inside the clock case. I would like to mount a power resistor in the case and use it as a controlled heater element to keep the temperature at a constant 78 degrees Fahrenheit. Could you suggest a 12-volt circuit that would maintain this constant case temperature?

Edward J. Wilk

A What you need is something that doesn’t disturb the air inside the cabinet so as not to upset the swing of the pendulum or dry out the wood. In other words, a gentle heat with no circulating fan. The circuit in Figure 6 has been around forever and can easily maintain the temperature to within three degrees Fahrenheit. The power resistor should be mounted on an aluminum heatsink and placed at the bottom of the case where convection will draw the heat up the column. You’ll have to experiment with the placement of the thermistor — a NTC (negative temperature coefficient) device with a resistance of about 2K at 80°F — for best results.

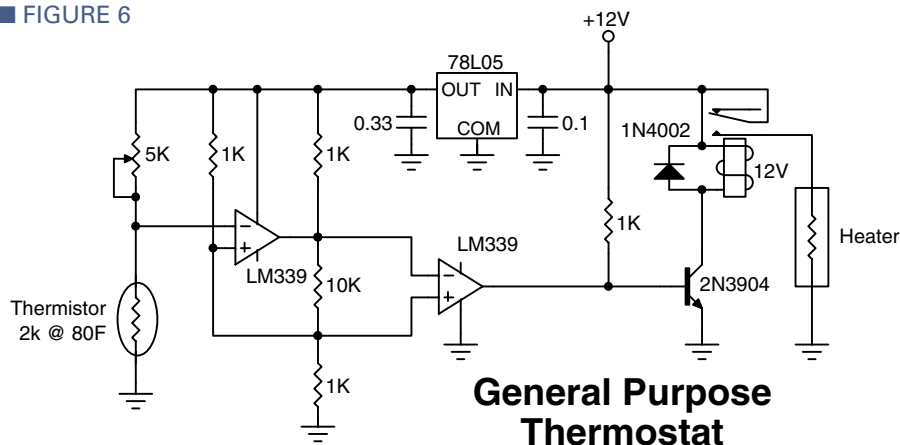
GHOST OF A MM5369 CLOCK

Q I am looking for a MM5369 chip that uses a color-burst crystal to generate a 50-Hz or 60-Hz timebase. I have been told that this chip is no longer available, but heard that you can make a substitute using two chips and a crystal. Have you seen this design?

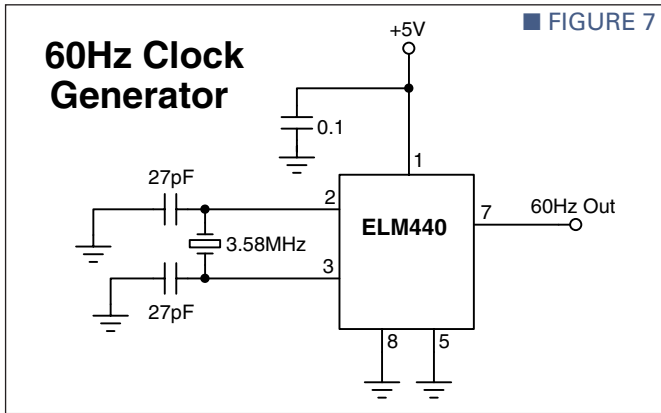
*Craig Kendrick Sellen
Carbondale, PA*

A ELM Electronics (www.elm-electronics.com) makes an ELM440 IC that does exactly what you ask (Figure 7); the ELM446 is a 50-Hz version. Both eight-pin devices are based on the 12C5xx family of devices from Microchip Technology, Inc., and are available in two sizes — either the standard DIP package, or in the smaller SOIC surface mount version. ELM has no minimum purchase (the

■ FIGURE 6



General Purpose Thermostat



ELM440 sells for \$8.00 CDN) and prices are the same no matter where in the world you are. All sales are on-line using major credit cards.

However, it's been my experience that most circuits reduce the 60 Hz down to 1 Hz before the clock is used. If this is your intent, it can be accomplished using the cheaper 4060 ripple counter and a 32.768 kHz watch crystal (Figure 8). The 4060 divides the 32 kHz crystal frequency by 16,384, resulting in a 2-Hz output. This is further divided by the 74HC112 J-K flip-flop to produce a pulse once every second.

ELIMINATING PA FEEDBACK

Q I just installed a new PA amplifier, Pyramid #PA1000X, at the company where I work. The amp works great, but since the installation, we have had problems with feedback whenever anyone tries to page using a cordless phone. I've tried reducing the speaker volumes somewhat, and although it does help, it is not a cure. Is there a preamp buffer circuit that I could build that would allow me to tune out the feedback and also limit the input volume level (ALC), so some of the loudmouths in the company don't overdrive the amp?

Dan Elliott

A If you have an equalizer laying around, it can be used to filter out the feedback frequency. Of course, you will have to experiment with different settings. Start with everything set with no boost

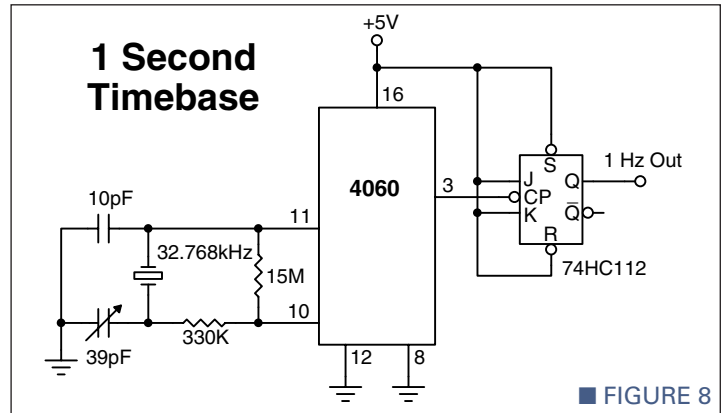
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or attenuation, then move the controls — one at a time — until you eliminate the unwanted frequency (be sure to return them to neutral before going on to the next filter). I'd start with the mid-frequencies first.

A guaranteed solution is to install a feedback eliminator. These units have a microprocessor in them that searches for the distinctive feedback fingerprint, determines the offending frequency, and engages a notch filter to eliminate it. The number of filters range anywhere from 10 to 80, with the price increasing with the number of filters. A good buy is the Behringer DSP 110 Shark — with variable audio delay and 12 notch filters — which sells on the street for \$80. **NV**

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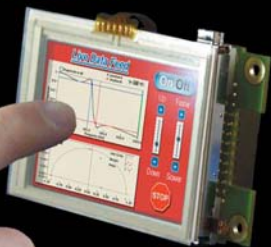
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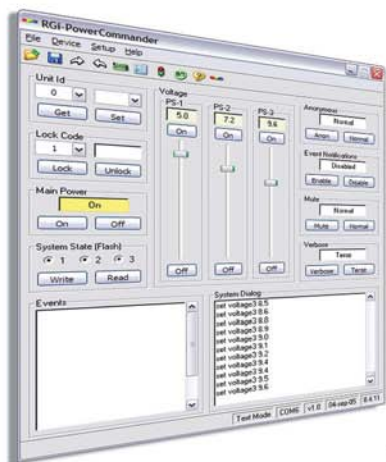
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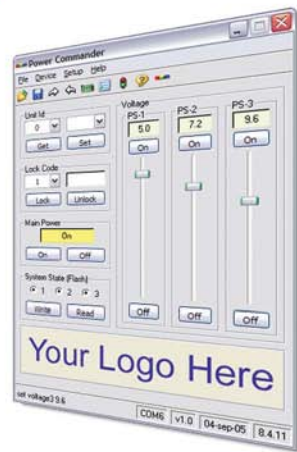
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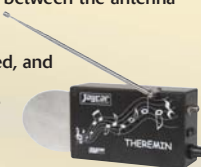
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■ BY JON WILLIAMS

PLAYSTATION ROBOT CONTROLLER

The other day my boss, Ken, pointed out that I have written over six years' worth of columns for *Nuts & Volts*. Wow. Aren't you guys tired of me yet? (Okay, don't answer that question!) For all the columns I've written, clearly one of the top three in reader interest was called "PlayStation Control Redux" (September 2003) where we delved more deeply into the PlayStation controller protocol work started by Aaron Dahlen. Well, between then and now, Parallax released the SX/B compiler for the SX micro and the speed issues we dealt with when using a BASIC Stamp are no longer issues. That, and Ken is building a cool new treaded robot that might need a full-featured control device — let's hack a PlayStation controller for him and let him drive that dude around, shall we?

During a recent conversation with a Parallax EFX customer, I was asked how difficult it is to learn SX assembly language — my friend is interested in building custom accessory devices for his props and holiday displays using the SX28. He was actually quite surprised to learn that, to date, all of the EFX accessory products (RC-4, DC-16, AP-8) that use the SX are actually programmed in SX/B — I know because I'm part of the team that designed those products and wrote a few of the programs myself.

Why did I use SX/B? Well, I'm part of the SX/B development team so I'm really comfortable with it and — here's the kicker — I still haven't taken the time to commit to learning enough assembly programming to write full-blown applications. What it actually comes down to is a lack of patience on my part, and with SX/B I really don't need to be; I can write very PBASIC-like code that gets compiled. I get the benefits of high-level programming with the execution speed of assembly language.

That said, SX/B is not a compiler in the terms that we typically think about, that is, SX/B doesn't optimize and automatically remove redundant code. Why not? The reason is that Parallax created SX/B so that those interested in assembly could learn from it — that's very tough to do when one looks at the assembly output of an optimized compiler. With SX/B, you can see the assembly output from your high-level code (which gets included in the comments) and see how the various instructions work "under the hood."

So does that mean SX/B is inefficient? No, I don't

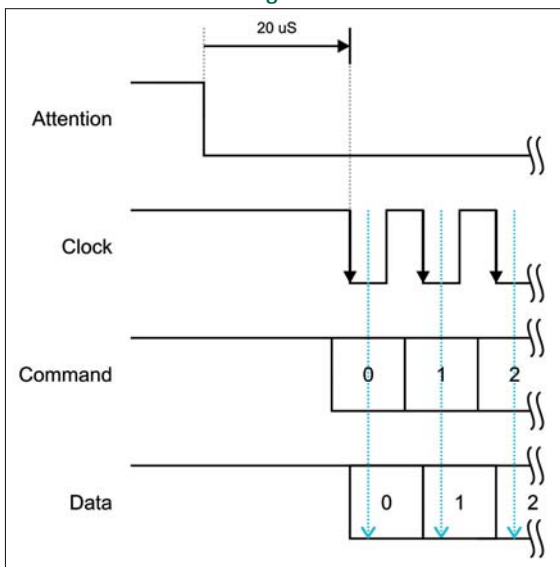
think so; it is what it is: an inline (some call "macro") compiler. The code we write gets compiled inline as it appears in the source file. If, for example, we have two consecutive **PAUSE** instructions, the code to execute **PAUSE** will be expanded twice — and this does use more code space. This is not a problem if we understand and design around it, and that's really what I'm going to focus on in this month's column.

If you look at enough of my SX/B programs, you'll notice that they are all similarly structured and, in fact, I reuse a lot of the same subroutines. The reason is this: By keeping my code consistent, I can follow my own programs and get back into them more quickly after a break and — here's the real important part for SX/B — by putting "big" (lots of assembly code required) instructions into a subroutine, those instructions only get expanded once and I'm able to conserve code space. The additional benefit to putting these commands into subroutines is that we can add our own (even optional) features to the routines. We'll see how just a bit later.

PLAYSTATION CONTROLLER PROTOCOL

It turns out that the PlayStation

■ FIGURE 1. PSX timing

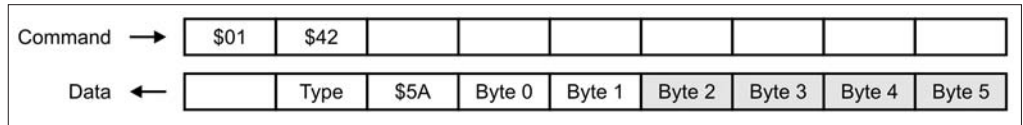


controller is actually very easy to connect to a microcontroller — in fact, it behaves just like a big shift register. The difference is that it has separate data in (called Command) and data out (called Data) lines. When we used the BASIC Stamp **SHIFTOUT** and **SHIFTIN** were used, but this created a problem with the last bit of data when using an analog controller. What we ended up doing was synthesizing a routine that could send and receive bytes at the same time, but in PBASIC, that's a little on the slow side. Not so with the SX, in fact, we now have to consider speed for the other side so that we don't do things too quickly.

Figure 1 shows the signal timing and relationships between the host and the PlayStation controller. Communication is initiated by bringing the P_{sx}Attn (attention) pin low. After a 20 microsecond delay, the bits are clocked in and out, with everything happening based on the falling edge of the clock signal.

From a programming standpoint, we need to put a bit (starting with the LSB) on the P_{sx}Cmd pin before pulling the clock line low. After the clock has been pulled low and we allow a bit of setup time, we can read a bit from the P_{sx}Data pin. We'll get into the specific code mechanics a little later.

Figure 2 shows the relationship of input and output bytes. The host transmits \$01 (start) and \$42 (get data), the PlayStation controller sends back its type, \$5A (ready), then two (digital controller) or six data bytes (analog controller). Note that the controller transmits its type while the host is sending the \$42 byte. What we're going to do as we develop this program is create a routine that does the equivalent of **SHIFTOUT** and **SHIFTIN** — but at the same time.



■ FIGURE 2. PSX exchange

WAIT_US	SUB	1,
2		
WAIT_MS	SUB	1, 2
RX_BYTE	SUB	
TX_BYTE	SUB	1
TX_OUT	SUB	1, 2
READ_PSX	SUB	
PSX_SHIFTIO	SUB	0, 1

Here's a secret: Only the last two subroutines are specific to this project; all the others form the core of most of the serial accessory projects I developed using the SX. Looking at the code you'll see that each subroutine has a name, followed by the keyword **SUB**, and then information on parameters used by each subroutine. Notice that not every subroutine requires parameters sent to it (like RX_BYTE) and most actually have a variable number of parameters. WAIT_US (a shell for **PAUSEUS**), for example, requires one parameter and can take two.

With the subroutines defined, we can jump into the main body of the program. As with similar devices, the PlayStation Helper chip is going to wait on a specific command header from the host and respond as instructed. We're going to use open-baudmode style serial communications with this product so that it's compatible with other serial accessories. By doing that, we could connect this device to a BASIC Stamp using the same serial line that commands a Parallax Servo Controller (PSC). With a BASIC Stamp, a PSC, and the PlayStation Helper you could put together a very cool robot.

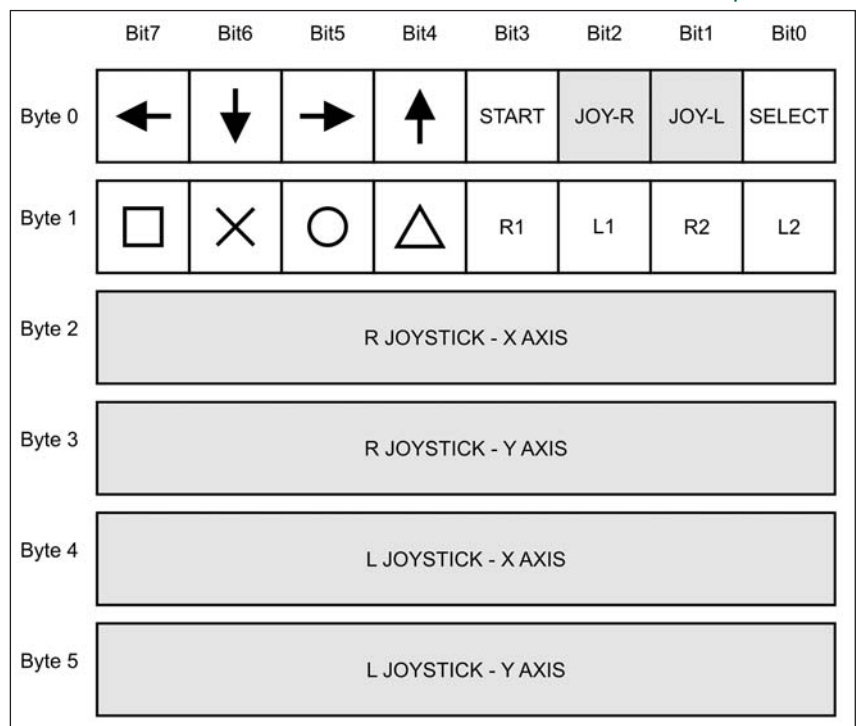
The Parallax AppMod

■ FIGURE 3. PSX packet bits

THE TAO OF SX/B

Okay, I know that's a bit of a cheeky section title, since almost every programming language can be manipulated in any way by an experienced programmer. So this is my Tao of SX/B, at least for serial accessory devices. Let's start at the top.

One of the features I like best about SX/B is the ability to define subroutines with the **SUB** keyword. This serves two important functions: 1) It causes the compiler to create a jump table that lets us put the subroutine code anywhere in memory (remember, in the SX, subroutines usually have to be in the top half of a code page unless a jump table is used); and 2) It lets us tell the compiler how many parameters are used by the subroutine. This allows the compiler to do syntax checks on our custom routines — very handy! Here are the subroutines used in the PlayStation Helper module:



protocol is really more of a configuration than a defined protocol — as I just stated, it uses open-baudmode communications and a text header that starts with the “!” character. For example, when we want to send a command to the PSC, we use the header “!SC” at the beginning of each command message. Let’s be logical, shall we, and use “!PSX” as the header for our PlayStation Helper. Okay then, let’s wait for the header:

```
Main:
char = RX_BYTE
IF char <> "!" THEN Main
char = RX_BYTE
IF char <> "P" THEN Main
char = RX_BYTE
IF char <> "S" THEN Main
char = RX_BYTE
IF char <> "X" THEN Main
```

You see, I told you it was simple. We grab one character at a time, compare it to the header sequence, and jump back to Main if anything is out of whack. Now, if you’re new to SX/B you’re probably wondering how this can work, that is, having a comparison between incoming serial bytes.

This works fine because the SX is running assembly language and even at the 4 MHz clock we’re using each instruction only takes 0.25 microseconds! At 38.4k baud, each bit is 26 microseconds long so there is plenty of time during the stop bit to get the comparison done. Remember, this code gets compiled to assembly language. Here’s a small section of the compiled code:

```
Main:
CALL @__RX_BYTE
MOV char, W
CJNE char, #"! ", @Main
```

The first line calls the RX_BYTE subroutine — note that @ is used so the subroutine call can cross code pages. On return, the value that was received is retrieved from the W (working) register; this takes one cycle. The comparison is just one line of assembly code, but is a compound statement that takes either four or six cycles, depending on the comparison result. Still, in the worst case, we’ve only consumed seven cycles — 1.75 microseconds — during the 26 microsecond window between bytes. I’m not suggesting we go crazy and try to squeeze a whole lot more (in actual fact a few more cycles are consumed with the call to and return from the RX_BYTE subroutine), but I want you to rest easy that when compiled, we can do the comparison as shown without any fear of missing the next serial byte.

Okay, speaking of serial bytes, let’s look at the code that handles that:

```
RX_BYTE:
SERIN Sio, Baud, temp1
IF temp1 >= "a" THEN
  IF temp1 <= "z" THEN
    temp1 = temp1 - $20
  ENDIF
ENDIF
RETURN temp1
```

This subroutine actually serves two purposes: it receives the serial byte and if the byte is a lowercase letter, it gets converted to uppercase. This subroutine points out

one of the changes in SX/B as it has matured and developed an expanding customer base, specifically the ability to return a value to the subroutine caller. As we saw in the compiled code above, the W register is used as the mechanism for handling the return value.

Let me emphasize one final time the reason for this subroutine: **SERIN** is a complex statement that requires several lines of assembly code. If we were to use **SERIN** every place in the program that required serial input, we would use a lot of code space with redundant code. And, by encapsulating **SERIN** in a subroutine, we’re able to add the lowercase-to-uppercase conversion feature.

Now that we have the header, the next step is to process receive and process the command byte sent by the host controller:

```
Get_Command:
char = RX_BYTE
IF char = "V" THEN Show_Version
IF char = "T" THEN Get_Type
IF char = "S" THEN Get_Status
IF char = "B" THEN Get_Buttons
IF char = "J" THEN Get_Joysticks
IF char = "C" THEN Config_IoPort
IF char = "W" THEN Write_IoPort
IF char = "R" THEN Read_IoPort
GOTO Main
```

After receiving the command byte, the program simply compares it to the list of commands available to the program. You may think that **LOOKDOWN** and **BRANCH** would be more efficient, but in practice, it doesn’t use any less code (after being compiled) and it’s not quite as easy to follow in my book.

The first command is “V” for version; this is a good idea to include in your designs, especially if you’re selling them as products and making incremental improvements. Providing a version number allows the end user to design around the features available in the product he has. On receiving the “V” command, the PlayStation Helper will send back a three-byte version string. Here’s the top level code:

```
Show_Version:
WAIT_MS 1
TX_OUT Version
GOTO Main
```

There’s no big mystery here; the only thing you may wonder about is the WAIT_MS 1 line. This inserts a one millisecond delay before returning the version string so that the BASIC Stamp can load up its **SERIN** instruction to receive the data from the SX. Here’s the code for WAIT_MS:

```
WAIT_MS:
temp1 = __PARAM1
IF __PARAMCNT = 1 THEN
  temp2 = 1
ELSE
  temp2 = __PARAM2
ENDIF
IF temp1 > 0 THEN
  IF temp2 > 0 THEN
    PAUSE temp1 * temp2
  ENDIF
ENDIF
RETURN
```

This is a subroutine that can handle a variable number of parameters (one or two). The first parameter is required and is the base delay time in milliseconds. If a second parameter is provided, this is used as a multiplier, otherwise the multiplication factor is set to one. The internal variable, `__PARAMCNT`, is used to check the number of parameters sent to the subroutine, and as you can see, it gives us a lot of flexibility. Finally, we check to see that neither parameter was set to zero and do the delay using the version of **PAUSE** that uses the multiplication of two bytes.

After the delay, we send the version string back to the host with `TX_OUT`. Let's look at that code:

```
TX_OUT:
temp3 = __PARAM1
IF __PARAMCNT = 2 THEN
temp4 = __PARAM2
DO
READ temp4 + temp3, temp5
IF temp5 = 0 THEN EXIT
TX_BYTE temp5
INC temp3
temp4 = temp4 + Z
LOOP
ELSE
TX_BYTE temp3
ENDIF
RETURN
```

`TX_OUT` is quite flexible in that it can be used to transmit a single byte or multi-byte strings (stored as z-strings). Again we use `__PARAMCNT` to determine the behavior of the subroutine. When a single byte is passed, there will only be one parameter. When a string is passed to the subroutine, two parameters are required due to the 12-bit size of the string address. In the case of returning the version to the host, two parameters will be passed to the subroutine: the base and offset address values of that string.

It's important to note that strings can be handled in two ways. For the version string, we're going to store it in a **DATA** statement like this:

```
Version:
DATA "0.1", 0
```

When we use a stored string like this we must append the zero terminator ourselves and we'll pass the string label to the subroutine — this gets resolved by the compiler to the base and offset memory locations. The nice thing about this subroutine is that it also lets us send inline strings like this:

```
TX_OUT "Nuts & Volts rocks!"
```

When we pass an inline string, the compiler adds the zero-terminator for us. Note that if we're going to send the same string more than once then the most efficient method is to store the string in a **DATA** statement.

Getting back to `TX_OUT` we see that it uses a **DO-LOOP** construct to transmit the string. **READ** is used to retrieve each character from memory and if it's zero, we're done (hence the use of **EXIT**). Remember that `SX/B` variables are bytes only but we're using a 12-bit address for the string characters. What this means is that when we increment the offset value, we need to update the base value on a roll-over. This is actu-

ally quite easy to do as the `Z` flag will be set (to 1) when we increment the offset from 255 to 0 — all we have to do is add the `Z` bit to the base after incrementing the offset. In most cases, the `Z` bit will be zero but when we have a roll-over, it will be set to 1 and the base will be updated properly.

Note that `TX_OUT` calls the `TX_BYTE` subroutine. This one is really easy; it simply makes a copy of the byte passed to it and then transmits it with **SEROUT** on the specified port at the program baud rate:

```
TX_BYTE:
temp1 = __PARAM1
SEROUT Sio, Baud, temp1
RETURN
```

In actual fact, `TX_OUT` started as `TX_STR` (transmit string) and always required two bytes. It was a simple matter to update the subroutine to handle one byte or two so the main code only ever needs to call `TX_OUT`. Yes, we could use `TX_BYTE`, but if we made a change from sending a byte to sending a string we'd also have to change which subroutine gets used. By only using `TX_OUT` in the main body of our program we never have to worry about that.

So far the program has been pretty generic — and that's the point. What I'm suggesting is that we can use this framework for a whole host of serial accessories that are useful for BASIC Stamp (and other microcontroller) projects. As I indicated earlier, this framework runs in the RC-4, DC-16, and AP-8 products that are part of the Parallax EFX line; you can do it too.

Let's get into the PlayStation-specific code. Remember that the PlayStation controller acts like a big, smart shift register, and it can receive and transmit data at the same time. Since **SHIFTOUT** and **SHIFTIN** do only one thing each, let's create a subroutine that handles the full-duplex nature of the controller.

```
PSX_SHIFTIO:
IF __PARAMCNT = 1 THEN
temp3 = __PARAM1
ELSE
temp3 = 0
ENDIF
temp4 = 0
FOR temp5 = 1 TO 8
PsxCmd = temp3.0
temp3 = temp3 >> 1
PsxClock = 0
WAIT_US 5
temp4 = temp4 >> 1
temp4.7 = PsxData
PsxClock = 1
WAIT_US 5
NEXT
RETURN temp4
```

This is definitely the trickiest subroutine in the program in that it can send a byte to the controller, it can get a byte from the controller, and it can do both at the same time. We'll see all three uses of the subroutine's capabilities in just a bit.

When the subroutine is called with an output parameter, that value is copied into `temp3` — if not provided, `temp3` is set to zero as this is the output byte to the controller. Before entering the transmission loop, `temp4` gets cleared; this is the input byte from the controller and will

be passed back to the caller. A **FOR-NEXT** loop is used to send and receive eight bits, and the transmission — in PBASIC terms — is LSBFIRST. The first step is to put the LSB (*temp3.0*) onto the P_{xCmd} pin and then pull the clock line low to output that bit. Note that we shift the next bit right before the clock to add a bit of timing delay before the clock change and to have the next bit in place for the next iteration of the loop.

After the clock line goes low, the controller will output a data bit (LSBFIRST) onto the P_{xData} pin. Here's where things can look a little confusing at first. We start by shifting *temp4* to the right by one bit and then placing the data line bit into *temp4.7*. We have to do this because we ultimately want the first bit read to end up in *temp4.0* — this will, in fact, happen after eight iterations of the loop.

One thing of note is the clock timing. I don't actually have a PlayStation console but I met a guy named Jim in the Parallax user forums who happened to borrow one from his nephew. He connected a 'scope and told me that the high and low timing of the clock line was about five microseconds. That's what I've been using and have never had a problem — I suspect it's probably a bit on the generous side, but I see no need to push it. At this speed it takes just about five milliseconds to get the entire packet from the controller.

And here's the code that does just that:

```

READ_PSX:
  PxAttn = 0
  WAIT_US 20
  PSX_SHIFTIO $01
  pxId = PSX_SHIFTIO $42
  pxStatus = PSX_SHIFTIO
  pxThumb1 = PSX_SHIFTIO
  pxThumb2 = PSX_SHIFTIO
  IF pxId = $73 THEN
    pxJoyRX = PSX_SHIFTIO
    pxJoyRY = PSX_SHIFTIO
    pxJoyLX = PSX_SHIFTIO
    pxJoyLY = PSX_SHIFTIO
  ELSE
    pxJoyRX = $80
    pxJoyRY = $80
    pxJoyLX = $80
    pxJoyLY = $80
  ENDF
  PxAttn = 1

  pxThumb1 = ~pxThumb1
  pxThumb2 = ~pxThumb2
  RETURN

```

This routine starts by pulling the P_xAttn line low to activate the controller. According to Jim, the PlayStation console waits 20 microseconds before transmitting the start byte (\$01) so I've put that into my code. For those of you that have used the BASIC Stamp to connect to the PlayStation controller, we need to keep in mind that it takes at least 100 microseconds to load each instruction so there's a lot of built-in delays. Since we're dealing with compiled code we have to manually put those delays in. The WAIT_US subroutine is identical to the WAIT_MS routine that we looked at earlier, the difference being that it uses **PAUSEUS** instead of **PAUSE**.

The READ_PSX subroutine shows the flexibility that we built into the PSX_SHIFTIO routine. We start by sending \$01 — notice that we don't care about anything that gets returned so there is no assignment. The next line, however, sends \$42 (get data) with PSX_SHIFTIO and assigns the return value to *p_xId*. This tells us what kind of controller is connected; it will usually be \$41 for digital controllers or \$73 for analog controllers. After the ID byte, the controller transmits a packet header of \$5A. After this, header controller sends two bytes of button data and, if in analog mode, four bytes of joystick data.

I happen to have a Sony analog controller that can be set to digital or analog mode. I made a decision for this subroutine to stuff the joystick bytes with \$80 if the controller is digital or set to digital mode. The value \$80 represents the center position of each joystick axis and allows me to simplify my BASIC Stamp programs. If we don't include this conditional code, then each joystick value will be set to \$FF (extreme right or down position) when in digital mode, and in my mind this is not the best value to return to the host.

Finally, the subroutine inverts the button bits so that a pressed button bit has a value of 1 when sent back to the BASIC Stamp.

Okay, now that we can read the controller, the command sections that handle the various requests for data are a breeze.

```

Get_Status:
  WAIT_MS 1
  READ_PSX
  TX_OUT pxThumb1
  TX_OUT pxThumb2
  TX_OUT pxJoyRX
  TX_OUT pxJoyRY
  TX_OUT pxJoyLX
  TX_OUT pxJoyLY
  GOTO Main

Get_Buttons:
  WAIT_MS 1
  READ_PSX
  TX_OUT pxThumb1
  TX_OUT pxThumb2
  GOTO Main

Get_Joysticks:
  WAIT_MS 1
  READ_PSX
  TX_OUT pxJoyRX
  TX_OUT pxJoyRY
  TX_OUT pxJoyLX
  TX_OUT pxJoyLY
  GOTO Main

```

As you can see, all of this code is very straightforward and gives us the ability to request from the PlayStation Helper module just what we need. Figure 4 shows the output from a simple BASIC Stamp controller that retrieves and displays the controller values (it's included in the download files).

Since this is designed to be a robot controller, let's take advantage of those spare pins on the SX28. By using the "C," "W," and "R" commands, we can configure, write,

and read the RC port. Just one caveat: the SX uses 0 to indicate an output bit, and 1 to indicate an input bit — this is exactly opposite of what we do in the BASIC Stamp (DIRS register). Knowing this, we will send BASIC Stamp style data to the PlayStation Helper module and invert the bits before assigning the configuration value to the TRIS register. Here's the code for handling the extra I/O port:

```
Config_IoPort:
  char = RX_BYTE
  PlpIO = char
  char = ~char
  TrisIO = char
  GOTO Main

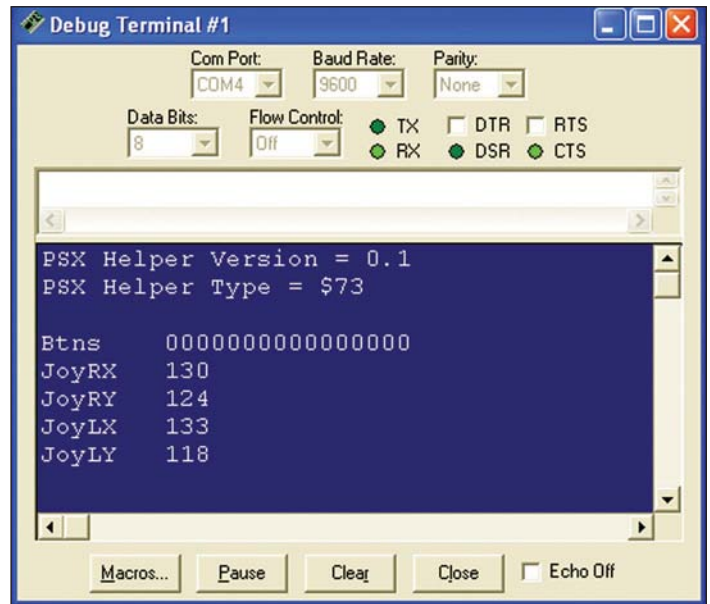
Write_IoPort:
  IoPort = RX_BYTE
  GOTO Main

Read_IoPort:
  WAIT_MS 1
  TX_OUT ~IoPort
  GOTO Main
```

One of the things that you'll notice about the Config_IoPort section is that the SX pull-ups are activated on any pin that is made an input. Now this means that inputs will be active-low, so we'll invert the bits sent back to the BASIC Stamp to make them look active-high — just as we did with the controller button bits.

WHAT ABOUT FORCE FEEDBACK?

To be honest, I was really hoping to conquer the force feedback motor control before using the SX with the PlayStation controller; sadly, every one of my attempts has failed. I have scoured the Internet for information and while there is some information out there, it is usually incomplete and not documented. What I'm going to be forced to do, I think, is rent or borrow a console and connect a logic analyzer to the PsxAttn, PsxClock, PsxCmd, and



■ FIGURE 4. PSX helper test output

PsxData lines to see exactly what happens when the motors are activated. Unfortunately, my friend Jim doesn't have a multi-channel logic analyzer and couldn't do that for me — and it's not something that can be done with a two-channel scope; one needs to know what the console and controller are doing and in relation to each other.

I tell you what ... if you have a console and are able to do that analysis for me, I will send you a shiny new Parallax Professional Development Board. Here's the offer: the first person that sends me working code, or enough information that I can add working code (that is, independent motor control through the serial link) to this project wins the PDB.

Until next time — Happy Stamping! **NV**

The PSX Helper Schematic can be viewed at the *Nuts & Volts* website at www.nutsvolts.com

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■ BY JAMES ANTONAKOS

WHY I AM GLAD MY COMPUTER CRASHED Twice, But Who's Counting?

IN MY ROLES AS AN EDUCATOR, AUTHOR, AND COLUMNIST, I utilize my computer extensively. There are many specialty software applications I use for drawing schematics, writing code, creating graphics, and working with images. I also use common applications such as Word, Excel, Email, and Internet Explorer.

Recently, I had two major problems. One turned out to be bad memory, which intermittently cause havoc, resulting in many fatal crashes involving dumping physical RAM to the hard disk. I brought a brand-new computer home to use while I worked on the old one.

The new computer failed today (today for me being Monday, November 15, 2005). It appears to be a magnificent failure at first glance, as the only thing you hear when power is applied is the sound of fans. No beep of any kind from the speaker (indicating POST is not running) and nothing on the display. Of course, it worked just fine a few hours ago. However, my humidifier is not working yet and it has been cold lately, so there is more static electricity in my home than usual. Maybe I blasted the CPU with a few thousand volts of static discharge.

Well, the main thing I learned when my first computer crashed was that I need a second computer. Not because my first one crashed, but it is useful to have a second computer for things like testing client-server network applications. Anyway, now my second computer has also crashed. So, it looks like my second computer needs a second computer,

and here I am using the basement computer shared by my four children and roughly 600 pieces of spyware.

Since I do not have my usual tools, this will not be a usual column. I am holding off on my Z8 Encore XP followup column till next time, where I will be able to announce the winners of the design contest (recall that I am giving away 10 Z8 Encore XP development kits).

Instead, I offer the following thoughts about several different topics. I hop across boundaries between computer science, electrical engineering, physics, and other areas.

IF I HAD A NICKEL FOR EVERY WASTED BIT

The format of an Ethernet frame consists of seven fields:

1. Preamble, seven bytes
2. SFD, one byte
3. Destination MAC Address, six bytes
4. Source MAC Address, six bytes
5. Type, two bytes
6. Data, 46 to 1,500 bytes
7. FCS, four bytes



Since the length of the Data field is variable, the total length of an Ethernet frame varies from 72 bytes to 1,526 bytes. If you add the lengths of all fields except for the Data field, you get 26 bytes. No matter how many bytes of data are contained in the frame (46 to 1,500), there are always 26 bytes of additional field information. Switching to units of bits, we have $26 \times 8 = 208$ bits of field information in each frame.

The way Ethernet is designed, there is always an idle time period after each transmitted frame. This is called the interframe gap, and it corresponds to 96 bits' worth of time. So, when transmitting an Ethernet frame, we use 156 bits for field information and 96 bits (96 bit times) for the interframe gap, giving 252 bits. Let us call this the "overhead."

If we transmit nothing but 72-byte, minimal-length Ethernet frame for an entire second, we will be able to clock out 14,880 complete frames using 10 Mbps Ethernet (100 nanoseconds per bit). Now, imagine how many bits are involved when we multiply 14,880 frames by the overhead of 252 bits per frame. Specifically, we are talking

about 3,749,760 bits. That is 37% of our 10,000,000 bit bandwidth. That leaves almost 6,300,000 bits for carrying data each second.

But hold on a minute. If we are exchanging data between a UDP or TCP application, the Data field of the Ethernet frame will contain two or more encapsulated protocols, such as IP carrying UDP, or IP carrying TCP carrying HTTP. Either way, the protocol headers take away another chunk of bits, leaving us with even less bits for carrying data.

On top of all that, we have assumed a perfect Ethernet network with no collisions. Any collisions will cause retransmission of the affected frames (after a random idle period), wasting even more of our precious bit budget.

In short, when you think of 10 Mbps Ethernet, be aware that all those bits are not being used as data bits.

LESS IS MORE, MORE IS MORE

As any digital electronics student may recall, the more logic gates you have in a circuit, the longer the propagation delay between the inputs and outputs. For example, a circuit with six gates connected in a series fashion, with one gate's output feeding the next gate's input, will have a cumulative propagation delay equal to the sum of the individual gate delays. If we pretend that each gate has an identical delay, say five nanoseconds, then the entire circuit has a delay of 30 nanoseconds. The significance of the gate delay is that we must wait for 30 nanoseconds after changing the inputs before we can change them again.

By reorganizing the circuit so that the gates function as a hardware pipeline, we might put three gates in each of two stages. This means that each stage has a delay of only 15 nanoseconds. By putting latches between the logic gates, each stage can be

clocked once every 15 nanoseconds. This means we can change the inputs every 15 nanoseconds, instead of every 30. We also get a new result at the output every 15 nanoseconds, instead of every 30. The pipeline can be operated two times faster than the original circuit.

If we divided the six gates into three groups of two gates each, the pipeline would have three stages, with each stage clocked once every 10 nanoseconds. The circuit can be operated three times faster than the original circuit. So, maybe you see why I say "less is more."

On the other hand, suppose we have a group of gates that perform a particular arithmetic operation for us, such as signed addition. Whether the gates are pipelined or not, the circuit takes a certain amount of time to do its job. If we add a second group of gates (another copy of the original circuit), it would appear that performance would suffer. After all, there are now two circuit delays instead of one. The trick, however, is to operate the two circuits in parallel. Thus, there is still only one circuit delay, but now two results are available instead of one. We change the inputs on both circuits at the same time, wait one circuit delay, and then read the results from the outputs of both circuits. More logic leads to more performance when parallelism is exploited. This is why I say "more is more."

THE SOCIAL LIFE OF A HONEYPOT



One summer, I set up a honeypot in my college office. A honeypot is a computer connected to the Internet that is deliberately vulnerable to attacks. There is no firewall to protect it, no router to hide its presence via NAT, no anti-virus or anti-spyware software running. The operating system on the computer was a freshly-installed copy of Windows NT Server with no service

packs or upgrades. In other words, the computer looked very attractive to someone looking for a computer to break into.

The initial infection took less than 24 hours and the winner was the Nachi worm, a nasty bandwidth hogger as it seeks other computers to infect. The honeypot went live on a Friday afternoon, and Monday morning my ISP was on the phone informing me of the infection. I asked the ISP technician how he discovered my computer was infected. He replied that my system was a "top talker" on the network, and his laptop monitors top talkers.

Even more interesting than that was what happened after the first attacker identified my honeypot as a vulnerable host. Within an hour, several 'buddies' had joined in the fun, with probes coming from lots of different IP addresses and networks. I can only imagine that once the machine was penetrated, word got out as one attacker told another and the party got started.

I ran a network sniffer program on the honeypot while it was being attacked and captured many attempts. I shared the capture files with my computer security and forensics students so they can analyze them and discover what happened themselves.

CONCURRENT VERSUS SIMULTANEOUS INSTRUCTION EXECUTION

What is the difference between instruction execution being concurrent or simultaneous? First, consider a single processor system, with the processor containing a single instruction execution unit. Concurrent execution means two or more threads of code are executed over a period of time, taking turns at the execution unit. To execute the two threads simultaneously, the processor would need to have a second execution unit, or you would need to add a second processor. Newer Intel CPUs provide both concurrent execution (via its

Hyperthreading technology) and simultaneous execution (via multiple pipelines).

SOMETHING SMALL TO THINK ABOUT

Have you ever heard the statement "like charges repel, unlike charges attract?" If you have ever tried to push two magnets together, South

pole to South pole, or North pole to North pole, you know the force of repulsion can be very strong. Applying this concept to the atom, the negatively charged electrons in orbit around the nucleus stay as far away from each other as possible. They do not leave the atom's orbit because they are attracted to the positively-charged protons inside the nucleus.

There is the problem right there. I

went through almost 35 years knowing the law of attraction and repulsion, without ever stopping to think: what keeps the protons together in the nucleus? They have the same charge, so what are they doing next to each other in the tiny, little nucleus? Well, they are pushing away from each other like crazy. But they are held close together in the nucleus by the Strong force, one of the four fundamental physical forces in the Universe. The Strong force only acts across short distances, namely the distance across the nucleus.

So, the protons are there to stay, unless radioactive decay occurs. Then many strange things happen. Otherwise, the only changes the atom may experience would be gaining or losing an electron from its orbit. Adding energy to an atom causes the electron orbits to increase in distance, moving the electrons farther and farther away from the nucleus, and lowering the attraction to the protons. Eventually, by adding enough energy, an electron gets far enough away to break free and begin roaming around as a free electron. Since electricity is the flow of free electrons from one location to another, we must be able to produce a lot of them to sustain the current in a circuit. Fortunately, there is enough heat energy in our everyday environment (even in the middle of the coldest winter) to create plenty of free electrons in copper, gold, silver, and other conductors.

What happens when there are too many of these high-energy electrons moving through a wire? The wire gets hot and possibly melts. Such powerful results from such a little thing.

I REALLY AM GLAD THEY CRASHED

So, yes, I am glad my computer (computers) crashed. The crash (crashes) allowed me to walk a different way for a change, and I like variety, surprises, and challenges. Plus, now that my column is finished, I can begin troubleshooting crash #2. But only after getting my humidifier running for the winter. **NV**

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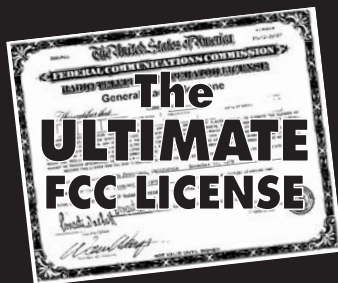
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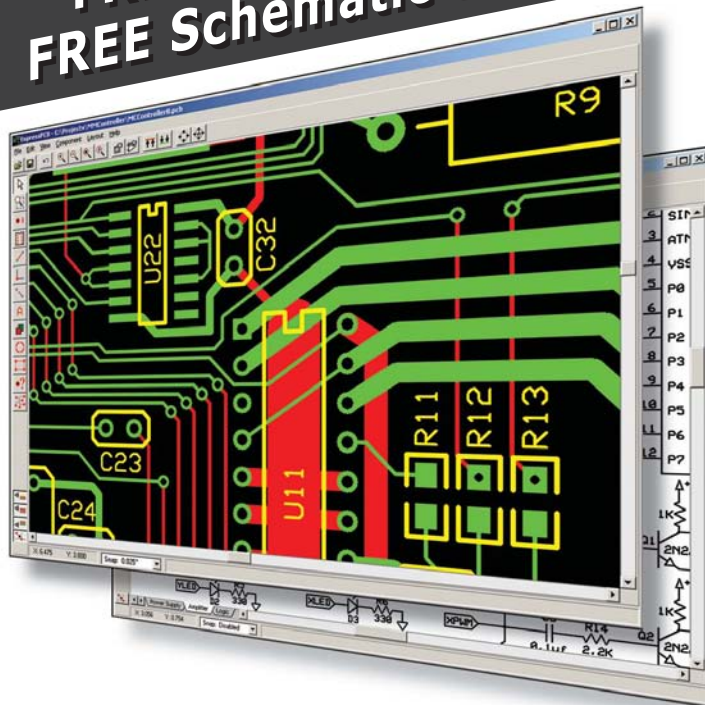
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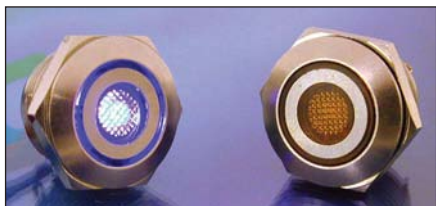
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APEM's highly secure AV Series pushbutton switches feature a stainless steel actuator with thermoplastic overmolding, available in a variety of colors. Actuator styles include illuminated ring or illuminated ring and disc models.

Electrical and general specifications include power ratings of 50 mA maximum at 24 VDC resistive load and an electrical life of one million cycles at full load. AV Series switches have an initial contact resistance of 100 milliohms maximum and a dielectric strength of 500 Vrms minimum (50 Hz minimum between terminals and 2,000 Vrms, 50 Hz minimum between terminals and bushing). Operating temperatures range from -30°C to +70°C. Additionally, the AV Series is available in both solder lug and straight PC terminals.

Material specifications include brass or gold plated terminals, gold

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CONNECT USB DEVICES OVER A QUARTER MILE APART

The USB standard calls for a maximum range of five meters (16.4 feet), but you can stretch this useful protocol to over 100 meters using standard UTP cabling, or as much as 500 meters (1,640 feet) by using fiber cable. This magic is made possible through the use of the new Ulinx™ USB Extender Modules from B&B Electronics.

"We're not fudging on the USB Standard," says B&B Electronics Director of Marketing (and past Director of Engineering) Mike Fahrion. "These are fully compliant with the USB specification. They deliver all of the benefits of USB, including remote device powering, plug and play operation, and cross-platform flexibility."

Ulinx USB extenders are composed of two separate units: the local extender and the remote extender. The user supplies up to 100 meters of Cat 5 cable or 500 meters of fiber optic cable to connect the modules. "It may even be able to use an existing cable, allowing you to use the copper



or fiber data lines you have in place now for USB devices," said Fahrion.

"The fiber conductor models bring an added benefit to the table," continued Fahrion. "Since fiber is inherently immune to electrical and radio interference, the fiber models give you surge protection and optical isolation. Many customers will purchase this product strictly for the isolation feature."

B&B Electronics has copper media models for USB Type 1.1 with ranges of 50 meters and 100 meters. A 50 meter version for USB Type 2.0 is also available. If fiber optic is your media of choice, there are 10 meter and 500 meter versions available.

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5 MHz DUAL CHANNEL HAND-HELD OSCILLOSCOPE

Extech Instruments, a major supplier of test and measurement equipment for the industrial marketplace, now offers a new 5 MHz Dual Channel Hand-Held Oscilloscope with built-in digital multimeter. Easy to operate and carry, the Model 381295 is microprocessor driven, features dual inputs with internal and external triggering, and allows the user to measure and graphically view two signals at the



same time. The 381295 is soft key menu driven and comes with Windows® compatible software that enables the user to display a live waveform on their computer screen and to control the operation of the meter remotely.

In addition to waveforms, the 381295 also allows the user to quickly and conveniently view true RMS AC/DC voltage, resistance, continuity, frequency, RPM, pulse width, and percent duty cycle. Advanced functions include the ability to store and recall up to 16 waveforms, freeze and hold a reading, and view DC voltage shifts in the slow roll mode.

Ideal for electrical, HVAC, electronic, and automotive applications, the 381295 features a super-twist, two-level display. The viewing screen of the 381295 is backlit for easy viewing and has a "window freeze" function that locks waveforms on it. Serving a variety of applications — such as sensor testing — it can also switch into "roll mode" for slow repetition waveforms. It has a sampling time of 25 MS/s for dual channel and 50 MS/s for single channel.

The 381295 comes complete with four test leads, four alligator clips, a protective holster, a Ni-MH battery pack, an AC adaptor/charger, an RS-232 cable, Windows compatible software, and a carrying case.

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RIO-8 EIGHT RELAY OUTPUT BOARD REDESIGN

Industrologic, Inc., announces the redesign of their popular RIO-8 Relay Board to allow jumper selectable configuration of the relay circuit options.

The Industrologic RIO-8 is an



eight relay printed circuit board assembly designed to allow micro-controller and other logic circuits to control high current loads. It features eight single-pole double-throw "Form C" relays with 10 amp contacts, and includes convenient terminal block connections, on-board back EMF suppression diodes, and LED indicators for each relay circuit.

The RIO-8 printed circuit board is physically arranged in two sections of four relays each, and each section has independent connections to its own terminal blocks, as well as connections between the two sections. This arrangement allows the board to be separated into two relay boards, if desired.

The board can be powered by 10 to 14 volts DC regulated or unregulated, and requires only enough current to power the relays to be operated plus their LED indicators.

The new version of the RIO-8 allows the relay circuits to be configured with convenient jumper plugs for one of two circuit configurations, and no longer needs to be ordered hardwired to a particular configuration.

The jumpers allow the circuits to be individually configured in one of these two ways.

First, the "open collector" configuration is used where the relays are operated by sinking the relay current to ground. This type of operation is typical of devices that have open collector transistor outputs.

Second, the "logic level" configuration is used with devices that have logic level output signals. These signals operate transistors on the RIO-8 that sink the relay current to ground.

Complete information and documentation on Industrologic's entire line of products is available at their website.

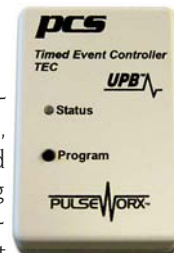
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TIMED EVENT CONTROLLER (TEC)

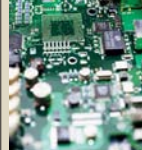
PCS (Powerline Control Systems, Inc.), a Northridge, CA based manufacturer of lighting control products, announces a new product addition called the TEC to its PulseWorx™ product line. The TEC, a programmable timer to automatically control PulseWorx lighting devices at preset times provides lighting automation without the need for an expensive home management system.

"For consumers who simply want the convenience of having certain lights come on at different times of the day, the TEC is the answer," explains Stan Mann, PCS VP and Director of New Business Development and Licensing. "It provides an affordable automated lighting control solution for people who don't need a full-fledged home automation system."

The TEC is part of PCS's PulseWorx line of residential lighting control products that utilize the patented UPB™ (Universal Powerline Bus) technology. The TEC can be programmed with 20 individual events which can occur between once a day to once a year. Based on geographic location, a built-in astronomical clock can automatically adjust for sunrise/sunset, leap year, and daylight savings. All programmed data is protected by non-volatile memory and can only be changed or deleted by reprogramming, regardless of power outage durations. A computer is used to program the TEC but scheduled events can easily be disabled from any UPB transmitter. All PulseWorx products are sold through authorized PulseWorx dealers, wholesale distributors, and professional integrators. These representatives sell, install, and support PulseWorx products to residential customers.



For more information, contact:
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■ THIS MONTH'S PROJECTS

Auxiliary RC Control Unit32

Weather Projects38

The Perceptron Circuit44

■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

●●●● Beginner Level

●●●● Intermediate Level

●●●● Advanced Level

●●●● Professional Level

The challenge seemed simple:

have an assistant control a camera or other piece of equipment on a remote controlled model aircraft while the pilot concentrates on flying the model.

AUXILIARY RC CONTROL UNIT

An obvious solution would be to use a second transmitter/receiver system on a different frequency. At our field, this is not a viable solution because only a limited number of units are allowed to be airborne at the same time.

Most RC systems have a trainer connection on the transmitter. Two transmitters are connected via this umbilical cord. The student's transmitter provides only the modulating signal to the main transmitter. A switch on the main transmitter allows the instructor to connect or disconnect the trainee. The only requirement here is that both units use the same number of channels and the same type of modulation. However, it is all or nothing. Either the instructor controls all the channels or the student has full control.

The primary channels, i.e., the first four channels are typically ailerons, elevator, throttle, and rudder. The remaining two or more channels are used for flaps, landing

gear, etc. The solution here is to replace control of the last two channels in either a six or eight channel system with signals from an auxiliary unit. For the purpose of this discussion, we will use a six channel system. The auxiliary control unit achieves this with a simple but elegant circuit without resorting to the use of a microprocessor. It should be noted that this scheme is limited to systems using pulse position modulation (PPM).

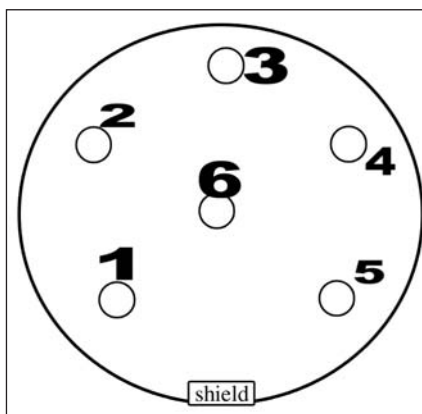
Tools and Circuit Board

The unit can be built using standard tools. It may be wire wrapped, point-to-point wired, or on a printed circuit board. I used a pre-printed board which worked very well. The only other tool required is a dual channel oscilloscope.

Prepare the Connecting Cable

You will need a six pin male connector to match with the connector on the back of the transmitter. Use a shielded cable with at least three wires. Pin 1 is +9.6 volts, battery negative connects to the shield of the connector; pin 2 is the PPM signal from the transmitter; and pin 3 is the PPM signal returning to the transmitter. Note that the power for the ACU (auxiliary control unit) is supplied by the transmitter. Figure 1 shows the connector as seen on the back of the transmitter.

■ FIGURE 1. Buddy box connector rear of transmitter



Signal Check

Use your oscilloscope and check the PPM signal from the transmitter. Use a voltmeter and check the presence of the battery voltage, typically 9.6 volts. The PPM signal for a six channel system is shown in Figure 2.

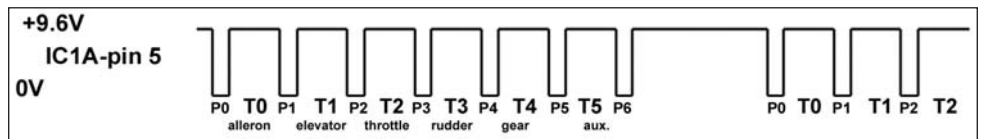
The pulses P0 to P6 are negative going in some systems, in others they may be positive going. The time slots, T0 to T5, will vary from one to two milliseconds. As an example, if the aileron control, T0, goes to maximum, T0 will be two milliseconds and all the pulses in the frame move up, but the time intervals T1 to T5 remain the same. After the last pulse, we see an extended period with no pulse present. This period is at least four milliseconds or more.

The Building Process

The easiest way to approach this circuit is to build it in sections. Since there is no feedback in the system you can build a section, test it, and then go on to the next section. Use Figure 5 as a guide to check your signals. Note that everything is referenced to the input signal on pin 2 of the connector. See Figure 3 for the complete schematic of the ACU.

Select a Box

Of course, we need a box to contain the circuit board and the controls. I used an old single stick transmitter and removed everything except the stick assembly. The potentiometers on this assembly were 5K ohm. Because of the limited movement of the stick, we have a range of about 1K ohm. With a slight adjustment of the potentiometers, we have a minimum resistance of 1K ohm and a maximum resistance of 2K ohm. The reason for this will become clear when we get to the regeneration stage. The photo in Figure 4 shows the assembly I used.



The Missing Pulse Detector

The first section starts with a double-pole single-throw switch. Because the trainer switch on the transmitter will be permanently set to the trainee position, the ACU operator must be able to relinquish full control immediately to the pilot. The switch has two functions: it connects the battery supply to the ACU circuit and connects pin 2 to pin 3. This has the same effect as the trainer switch on the pilot's transmitter.

You can now wire in IC1, a CD4538. This IC contains two re-triggerable multivibrators used as the missing pulse detector. R1, 6.8K ohm protects the input of IC1A. R2 and C1 are the timing elements causing the multivibrator IC1A to output a pulse of approximately 2.2 milliseconds — slightly longer than the longest timeslot in the pulse train. However, if a trigger pulse comes along before the multivibrator times out, the timing sequence starts again. Pin 7 of IC1A will show a negative pulse slightly longer than the total pulse train. During the rest period in the pulse train (see Figure 3), pin 7 will go positive again. This causes the second multivibrator, IC1B, to trigger. Its timing is controlled by the R3,C2 pair causing a positive output pulse of 300 microseconds on pin 10 of IC1.

The Decoder Stage

IC2 is a divide by 10 counter, CD4017, used as a serial to parallel converter. IC3 is a hex inverter, a CD4049. The PPM pulse train is used as a clock signal for the counter which we use to decode the pulse train, i.e., find the pulse we need to split the pulse train in two sections. Because the clock pulse must be positive, we invert the PPM signal with one stage of the hex inverter. The remaining five stages of

■ FIGURE 2. Six-channel PPM signal

the hex inverter are not needed. Make sure to ground their respective inputs to avoid unwanted oscillations. The 0.3 millisecond pulse from IC1B resets the counter. Run a test with the oscilloscope to make sure we have got this right. Check the stages Q0 through Q5 for a six channel system, or Q0 through Q7 for an eight channel system.

The Trigger Stage

IC4, CD4093 is a quad two-input NAND Schmitt trigger. IC4A is used as an AND gate. One input is from IC2, Q5. This signal goes high at the fifth pulse in the pulse train. The second input is the clock pulse for IC2. The output of IC4A goes high for the duration of the clock pulse and provides the trigger for the PPM regenerator, to be described later. The last stage of the trigger section is a differentiator C3 and R5. The positive pulse from IC4B produces a positive pulse coincident with the start of the pulse and a negative pulse coincident with the trailing edge of the pulse. IC4C inverts the negative pulse into a positive pulse for the next stage.

JUST A LITTLE NOTE

To understand why IC7 acts as a non-inverting comparator and IC8 as an inverting comparator consider the following statements:

1. Current will flow through the open collector when the voltage at the PLUS input is lower than the voltage at the MINUS input.
2. Current WILL NOT flow through the open collector when the voltage at the PLUS input is higher than the voltage at the MINUS input.

I am indebted to Ron Paisley for this concise and illuminating statement. His website has some excellent explanations of comparators and operational amplifiers. You'll find him at <http://home.cogeco.ca/~rpaisley4/circuitindex.html>

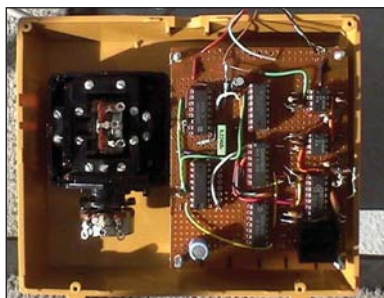


FOR THOSE WHO BOLDLY GO

and wish to do things a little differently ... IC3 is a hex inverter. I was not sure whether I would need more inverters downstream. As it turns out, one was enough. If the pulses are positive going, you can leave out the inverter stage or use two stages in series. Or you can use a LM311 for the inverter stage. The PPM regenerator stage uses the NE555. You could use four 555s or two 556s. Just remember that these devices produce negative going pulses so you need to rework the output stage, as well. Whatever you do, build it as shown or a variation of it, like it or dislike it, let me know. I'll be glad to hear from you. You can reach me at pjw.rc.solutions@globetrotter.net

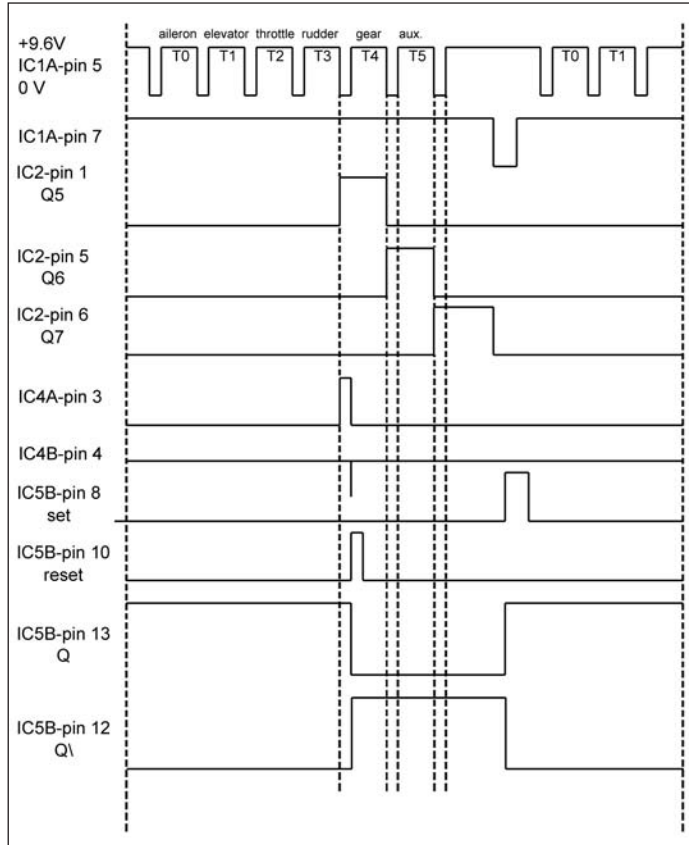
The Output Switching Stage

IC5B is a D type flip flop. With the clock and data inputs grounded, it becomes a simple set-reset circuit. The output of IC1B is a positive pulse indicating that the missing pulse detector has found the end of a pulse train and the beginning of the next pulse train. This pulse sets IC5B forcing the Q output to go positive and Q₁ to go negative. The trigger pulse from IC4C to the reset input of IC5B forces Q to go negative and Q₁ to go positive. To sum this up, the Q output of IC5B is positive and Q₁ negative for the first five pulses of the original signal from our transmitter. Conversely, Q will be negative and Q₁ positive for the remainder of the pulse train.



■ FIGURE 4. Hybrid arrangement

positive pulse of 300 microseconds. The negative going edge of this pulse triggers IC6C, another one to two millisecond delay. The last stage, IC6D, outputs again a 300 microsecond pulse. To sum it up, we have a positive pulse one to two milliseconds delayed with respect to pulse five of the original pulse train



■ FIGURE 5. ACU waveforms

and another positive pulse again delayed by the requisite one to two milliseconds. These two pulses are combined, or to put it properly, they are OR'ed via R18 and R19. Diodes D1

The PPM Regenerator Stage

IC6 is an NE558 quad timer. There are four independent stages inside the NE558. The outputs are open collector. The first timing element is IC6A. It is triggered on the negative going edge of the trigger produced by IC4A. Timing components are (R6+R7) x C4. R6+R7 are either a total of 1K ohm or 2K ohm. Combined with C4, this stage produces a positive output pulse with duration of one to two milliseconds. The next stage, IC6B, is triggered by the negative going edge of this pulse. The timing RC combination of IC6B, R8 x C5, gives us a

PARTS LIST

All resistors are 1/4 watt, 5% tolerance, and are available from any of the usual suppliers. For C1 through C7, use non-polarized, 1% mylar or ceramic types. These are part of the timing sequences and should be quite stable. C8 is an electrolytic used for bypassing the battery voltage.

The integrated circuits are CMOS. This choice is dictated by the fact that the nominal supply voltage from the transmitter is 9.6 volts. The same functions can be obtained with TTL but it would require the use of a five volt regulator and would put considerably more demand on the transmitter's battery. Note that in North America these CMOS devices are CD**** but in Europe, notably the same devices from Philips are named HEF****. All of the data sheets for the ICs can be found on the Internet.

QTY	LOCATION	DESCRIPTION	DATA SOURCE
□ 1	IC1	CD4538 Retriggerable multivibrator	Fairchild
□ 1	IC2	CD4017 Divide by 10 counter	Fairchild
□ 1	IC3	CD4049 Hex inverter	Philips or RCA
□ 1	IC4	CD4093 NAND Schmitt trigger	National
□ 1	IC5	CD4013 D type flip-flop	RCA
□ 1	IC6	NE558 Quad timer	Fairchild
□ 2	IC7,8	LM311 Voltage comparator	Texas Instrument
□ 1	X1	PP0308 Six-pin line plug	Jaycar Electronics



and D2 are necessary to prevent IC6D to trigger IC6B.

The Output Stages

IC7 and IC8 form the output stage of the ACU. The output

stage is made up of two LM311 Integrated circuits. Although they appear on the schematic as operational amplifiers, they are, in fact, differential comparators. The output of a comparator is an open collector or open emitter stage. This allows us to combine two or more outputs into a single output.

The LM311 has another interesting feature. Normally, pins 5 and 6 are part of the balancing circuit. This can be used to offset small differences in supply lines or input circuits. In our case, by tying pins 5 and 6 together, we can switch both input and output of the LM311 on or off. To effect this switching, we connect a 2N3904 transistor from pins 5 and 6 to ground. For example, pin 13 of IC5B is high during the first five pulses of our signal. Transistor T1 is fully turned on and IC8 is therefore turned off. At the same time, pin 12 of IC5B is low, transistor T2 is not conducting and IC7 is operating as a normal amplifier. Build IC7 and all its components first and check that the output only shows the first five pulses of the original signal. Build IC8 and its components; its output will be the two pulses from the regeneration stage. You can test this stage first by connecting a 1K ohm resistor from pin 7 to V+. If you are satisfied, remove this temporary resistor and connect pin7 of IC7 to pin 7 of IC8 to combine the signals.

When building the output stage, note the subtle difference between the two LM311s. The input to IC7 is a string of negative pulses, but the input to IC8 is a string of two positive pulses. IC8 therefore must invert these pulses. **NV**

ACKNOWLEDGEMENT

It has been said that no man is an island. As a corollary, no project is without external sources and stimulants. To that end, my thanks go to Krishna Blake of the West Island Aeronautics Club for suggesting the project and lending assistance whenever necessary. To the manufacturers of electronic components whose websites are a wealth of useful information and to all the individuals who find the time to fill their website with whatever I seem to require at any particular moment.



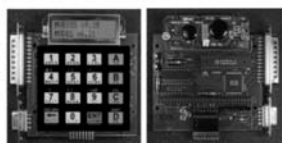
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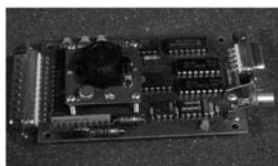
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Solutions That Work



Two easy undertakings for individuals who like electronics and who also like to watch the weather are presented in this article.

Essentially, they are “nuts” and mostly no “volts” projects.

■ PHOTO 1. Basic ingredients.



■ PHOTO 2. Close-up of plastic lawn furniture side tables.



WEATHER

PROJECTS FOR THE ELECTRONICS ENTHUSIAST

Two easy undertakings for individuals who like electronics and who also like to watch the weather are presented in this article. Essentially, they are “nuts” and mostly no “volts” projects. The first involves constructing an outdoor weather instruments shelter suitable for housing wireless thermometer and hygrometer transmitters that are used in conjunction with temperature and humidity readouts placed in the home. The second is for building a simple rain “chime” that allows for the

indoor listening of the amplified sound of falling raindrops on the equivalent of a sheet metal roof.

Easy to Build Instrument Transmitters Shelter

Like most weather aficionados, I have a number of wireless electronic thermometers and wireless electronic weather stations scattered around the house with the associated instrument transmitters attached to the railing on the back porch. This arrangement doesn't work very well, as the back porch catches direct sunlight during some point during the

■ PHOTO 3. Completed shelter.



day, sending the sensors into overdrive. An elegant cure is to build a simple version of a weather instrument shelter called a Stevenson Screen. This can easily be constructed from a two-pack of open-louvered fiberglass shutters, two outdoor plastic lawn furniture side tables, some two-inch plumbing parts, and several dozen stainless steel nuts, bolts, and washers.

Photo 1 shows the basic ingredients before cutting. The two 14" x 35" fiberglass shutters were cut to produce the four 14" x 17.5" sides of the shelter, and were then bolted together and then bolted to one of the plastic side tables used as the base. Two different side



■ PHOTO 4. Transmitters' mounting assembly.

tables (Photo 2) were involved in the construction of the shelter. I used the table shown to the left in Photo 2 for the base because the large scalloped corners allowed for better air circulation. The other table (with the less scalloped corners) was used (minus the legs) as the roof of the shelter.

Because this shelter is intended for transmitters only, no door is needed to access instruments on a daily basis; instead, entry is gained through the roof, which was attached to the fiberglass shutter assembly using two bolts, washers, and wing nuts. Photo 3 shows the completed unit and Photo 4 shows the transmitters mounting assembly fabricated from two-inch plumbing parts cemented to the plastic side table base. A 12-inch long PVC plastic pipe was fitted with a PVC general-purpose area drain to act as the base of the unit. (I used the PVC drain because I couldn't find a two-inch PVC flange.) A two-inch to four-inch PVC coupler was attached to the other end of the pipe and provided the mounting surface for the transmitter holders. I bolted the entire shelter to a 2' x 2' x 2" concrete garden pad placed in my backyard (Photo 5). It's functional, not bad to look at, and best of all, is made of non-weathering parts.



■ PHOTO 5. Shelter placed in the yard next to a digital rain gauge.

Electronic Rain Chime

If you like the sound of rain falling on a sheet metal roof, then this project will satisfy that desire — even if you live in a house with a shingle-covered wooden roof. The electronic rain chime shown in Photo 6 consists of a ceramic microphone element (Electronic Goldmine at www.goldmine-elec.com, G5098) mounted beneath an inverted stainless steel bowl that has been attached to a four-inch PVC pipe coupling using four-inch standoffs. RG-6 coaxial cable buried in the ground was used to connect the microphone

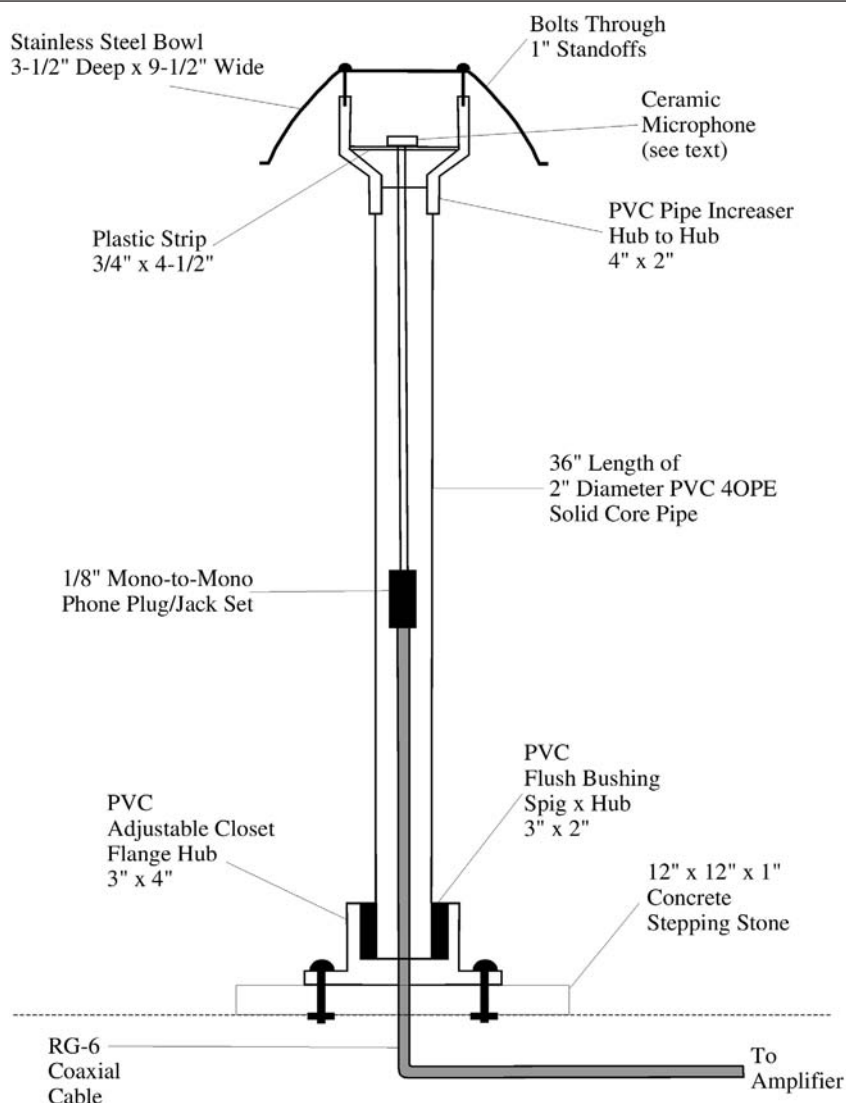
element with an indoor amplifier and speaker (Photo 7). I also used Electronic Goldmine's Megaphone Kit PA (C6746), which is comprised of a high gain electric microphone coupled to an IC audio amplifier, in a second rain chime that works as well as, if not better than, the ceramic microphone used in the prototype. Construction details are given in Figure 1, and a photograph of the inside of the "chime" head is presented in Photo 8. The PVC connectors I used to mount the head to two-inch PVC tubing were parts I happened to have on hand. Much easier coupling arrangements are possible, as indicated in Figure 1. The

■ PHOTO 6. Completed rain chime.



■ PHOTO 7. Mini amplifier and speaker.





■ PHOTO 8. Oblique view of the inside of the "chime" head.

■ FIGURE 1. Construction details of the rain chime.



■ PHOTO 9. View of the cement garden block mounting arrangement.

entire assembly, "chime" head, and column were mounted via a flange to a 1' x 1' concrete garden block (Photo 9). When it rains, I turn on the amplifier to listen to the metallic "plink, plink" of raindrops hitting the steel bowl. When it pours, the noise is thunderous. Those more electronically gifted than I should be able to figure out a way to turn these "sounds" into calibrated rainfall rates. **NV**

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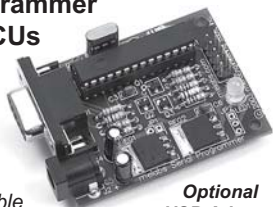
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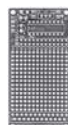
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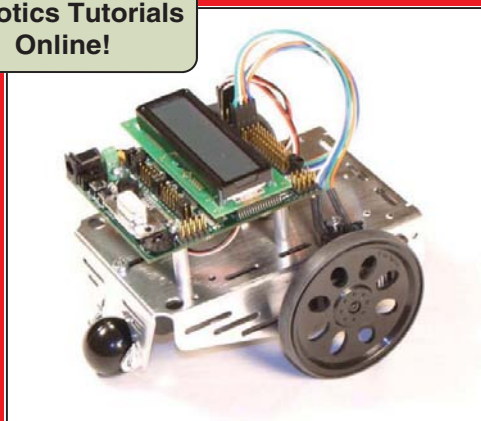
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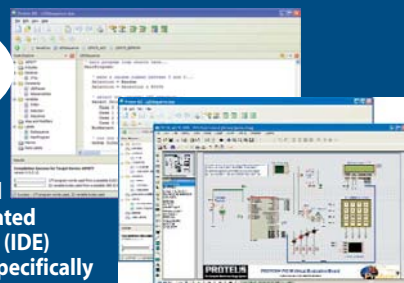
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We've talked about air pressure, now let's talk about elevation! The incredibly precise 24 bit A/D converter in the UP24 looks at the air pressure and converts it to elevation above sea level. In both graph and text, the elevation is displayed to a resolution of 1/3"! Yes, I said 1/3 of an inch! The applications for the super accurate elevation meter are endless. From watching and recording elevations during hiking trips to measuring and recording the wave heights on boats! Let your imagination take over from there!

What if you're in the field and you want to save data captured in your UP24? The built-in FLASH storage provides 13,824 samples of storage. Then you can transfer your data to your PC with a standard USB interface.

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Needless to say, you cannot put all the specs and screen shots in the limited space of this ad! Visit our website at www.ramseykits.com for full specs and information. If you're looking for the finest air pressure and elevation sensor, check out the UP24, truly a marvel in the industry! Available in a ready-to-build kit or a factory assembled and tested version. Check our website at www.ramseykits.com for more information!

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This article will show you how to build your very own electronic analog neuron, named the “Perceptron.”

Creating a single neuron may not seem earth shattering in the grand scheme of things, considering that your brain has over 10^{10} of them!

However, a neuron is the fundamental building block of intelligence.

THE PERCEPTRON CIRCUIT

The Perceptron circuit provides a hands-on way to demonstrate the principles of neuron operation, and also allows you to explore basic Boolean logic functions. Last but not least, it is a cool gadget to have sitting on your desk to impress your hacker and/or nerdy friends.

Whether biological, electronic, or software, the basic operation of a neuron is fairly simple at a high level. Of course, a biological neuron is quite a bit more complicated than the others. But relatively speaking, whether we are talking about a brain or neural network program, the basic concept is that the processor is simple by itself, but when combined with many others they collectively perform a complex computation. Compare this to the computer on your desk — how many processors does it

have? Essentially one, not counting some special processors in the video card and other peripherals.

Ready, Aim ... Fire!

A neuron receives one or more input signals and produces an output signal (Figure 1). What happens in between comprises the fundamental properties of a neuron — Neuron Property #1 and Neuron Property #2.

The activation function, which is also called a “squashing” function in neural network jargon, is usually nonlinear and also serves as a limiting operation to keep the output signal in a bounded range.

Mathematically, the neuron’s operation is represented as:

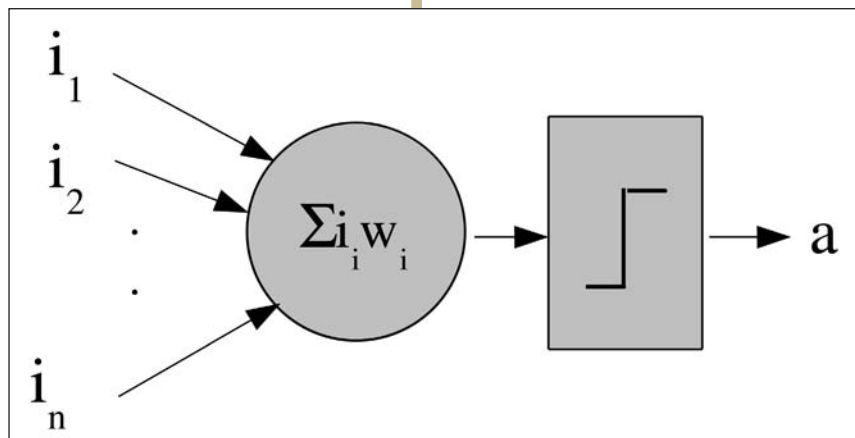
$$a = \text{squash}(\sum(i_i w_i))$$

where:

- i_i is input i to the Perceptron
- w_i is the weight for input i
- a is the activation (output)
- and:

$$\text{squash}(x) = 1; \text{ if } x > \text{threshold} \\ = 0; \text{ otherwise}$$

In English, the weighted sum is computed by multiplying each input by a weighting factor (simply called a weight), which dictates the importance of that input to the neuron’s computation. A small



■ FIGURE 1. Neuron Model.

weight means that input is not as important as an input that has a larger weight. The weight may also be negative, which means that the input tends to inhibit the output of the neuron. By summing all of these individual multiplications, we get an output that depends on how big the inputs are and how important each input is (as dictated by its weight).

The second operation is to perform a squashing function on the sum that was calculated in the first step. Neural network researchers experiment with different types of squashing functions, but they generally do two things.

First, they limit the range of the output value, and second, jump suddenly between states. A simple but useful type of squashing function is a simple threshold. If the sum is above a certain value — the threshold — the function jumps to the maximum value, otherwise it jumps to the minimum value.

Decades ago it was realized that in order to perform interesting computations in a neural network, the neuron needed to exhibit this nonlinear behavior.

Our electronic Perceptron is designed to perform this two-step computation of weighted sum plus threshold operation. We will see how this can implement simple, but interesting, functions including simple Boolean logic.

From the outside, the Perceptron consists of two inputs each of which is controlled by a switch and a potentiometer knob. The output is indicated by a single

NEURON PROPERTY #1:
A neuron computes a weighted sum of its inputs.

NEURON PROPERTY #2:
A neuron performs an activation function on the weighted sum.

dual-color LED. Inside, an analog amplifier chip and a handful of other components perform the computation. A single 9V battery is used to supply power.

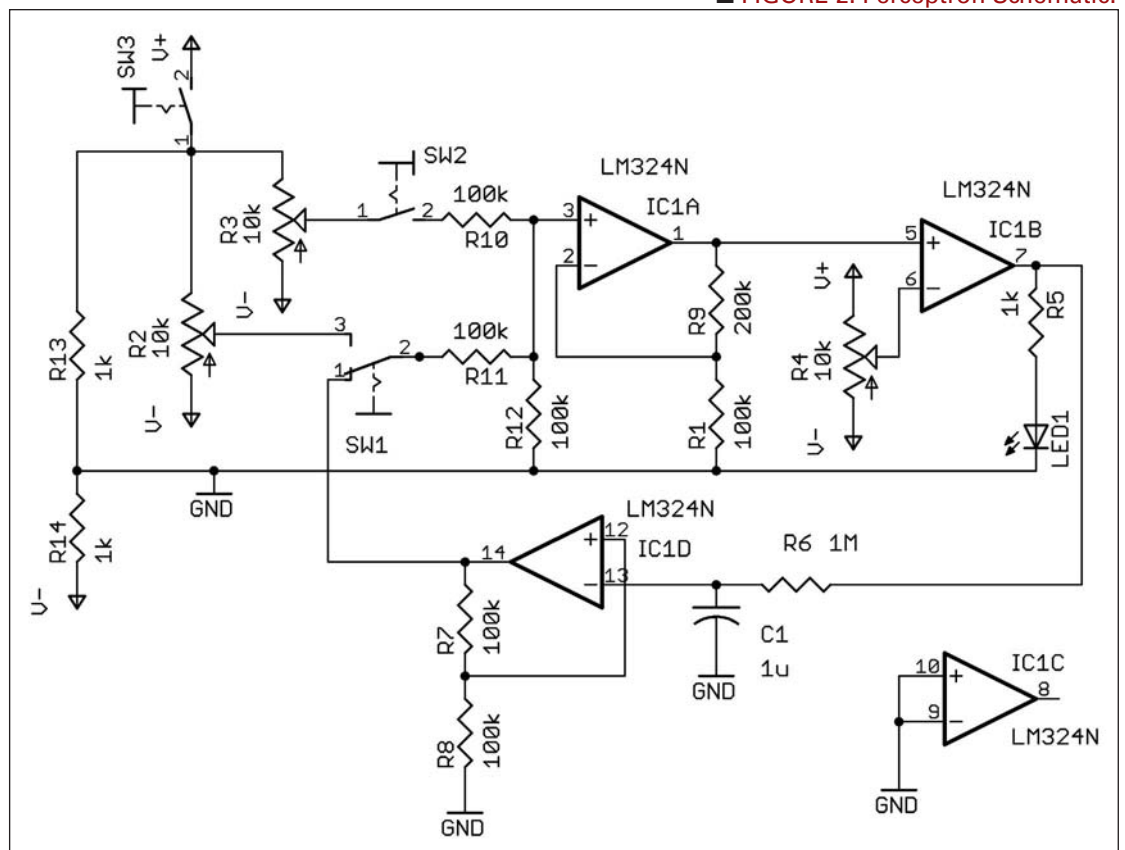
Circuit Operation

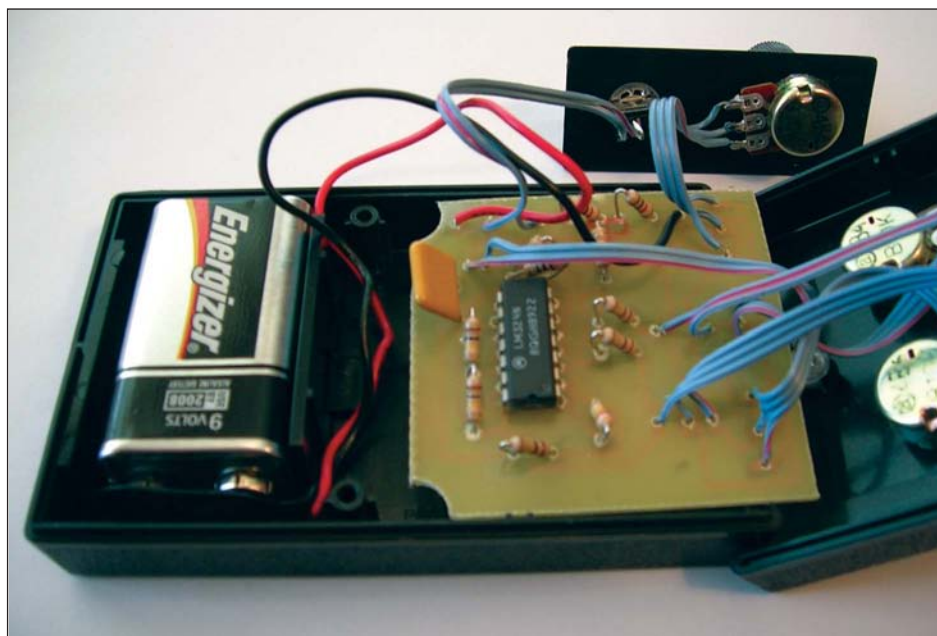
The schematic for the Perceptron is shown in Figure 2. The circuit is based on an LM324 quad op-amp (IC1), which was chosen for its tolerance to supply voltage used. A basic design goal was to have the Perceptron run off a single 9V bat-

tery. However, the circuit needs both positive and negative voltages to represent positive and negative weights. Therefore, a single-supply divider consisting of R13 and R14 is used to create a virtual ground and simulate positive and negative voltages.

This is a common op-amp technique, but it is normally advocated for AC signals only. However, by carefully referencing all appropriate signals to the virtual ground, the technique works fine for DC signals.

■ FIGURE 2. Perceptron Schematic.





■ **FIGURE 3. Circuit Board in Enclosure.**

The first part of the circuit handles the inputs and weights. Since our input signals — as represented by the two toggle switches — are binary (either on or off), we can use a simplifying trick to simulate the weighting operation.

To represent each input weight,

potentiometers R2 and R3 are connected across the full supply range. If the pot is turned toward the positive supply rail it represents a positive weight, and a negative weight when turned toward the negative supply. When the pot is in the center of its range, it represents

a zero weight. Each toggle switch is used to simply indicate whether an input is active (binary 1) or not (binary 0) by connecting/disconnecting its corresponding pot.

The first op-amp IC1A is configured as a non-inverting summing circuit, to sum the voltages from the two inputs. Resistor R12 is used to tie the summing point to ground in case of no inputs. That takes care of Neuron Property #1. In order to implement Neuron Property #2, we need the squashing function. To realize this, the output of summer IC1A is fed into op-amp IC1B, which is configured as a comparator. The third pot R4 on the negative input sets the threshold of the

neuron. Since the amp operates in open loop mode, the high gain will drive the output of the amp to the positive supply if the positive input is above the threshold voltage, and toward the negative supply voltage if it is below. In this mode, it acts mostly as a hard step function, although there is some “play” around the zero voltage point. The LED — with its limiting resistor at the output — indicates whether the output is high or low. The bidirectional LED given in the Parts List results in a green or red signal, which is more interesting than a single-color LED.

This is all that is needed to implement the basic neuron operation. To make things a little more interesting, a third op-amp IC1D from the LM324 is configured as an analog inverter and can be used to feed back the inverted output as an input to the neuron. This can be used to realize a simple oscillator, which will be covered later in the article.

Construction

A printed circuit board pattern is provided on the *Nuts & Volts* website (www.nutsvolts.com) if you want to create a PCB along with the parts layout. But you don't have to take this approach — the circuit can be constructed using simple perfboard and soldered wires. If you are not very good at soldering, you should consider using a 14-pin socket and place the chip in after you are done soldering. If you use a socket, it is easier to solder this in first — otherwise you can save soldering the IC for later in order to minimize the risk of heat damage.

Next, solder the resistors and capacitor to the board, followed by the 9V battery clip. You don't have to be paranoid about too much when soldering but as always, you should try to make good solder connections. The rest of the components — switches, pots, and LED — will be soldered using insulated wire. I like

PARTS LIST

SEMICONDUCTORS

- IC1 LM324N quad op-amp
- LED1 T1 3/4 dual color red/green, two-lead LED

RESISTORS (all 1/4W, 5%)

- R1,R7,R8,R10-R12 100K
- R5 470Ω
- R6 1M
- R9 220K
- R13,R14 1K
- R2-R4 10K linear pot

CAPACITORS

- C1 1μF 16V ceramic or other nonpolarized

ADDITIONAL PARTS AND MATERIALS

- SW1 SPDT center off submini toggle switch
- SW2-3 SPST submini toggle switch
- Knobs (to fit potentiometers), case (PacTec HM-9VB 4" x 2 1/2" x 1" or similar), LED holder, 9V battery connector, PCB or perf board, 14-pin socket, ribbon cable or other hookup wire, 9V battery

to use hookup wire scavenged from a ribbon cable. The wires are thin and flexible and I can peel off as many conductors as I want for the particular component I am connecting. However, feel free to use single insulated wires or multiconductor hookup wire.

It is always good to double-check the supply and ground connections on the chip and battery connections, especially if you are using perfboard.

The Parts List includes a case with a battery compartment that the circuit can be built into. Figure 3 shows the completed circuit board inside its enclosure. For the case listed in the Parts List, it was necessary to remove some material from two of the corners of the PCB. Figure 4 shows the completed Perceptron.

Testing and Using the Perceptron

The inputs of the Perceptron are controlled by a switch and a potentiometer (knob). Each knob controls the weight on its corresponding input. Clockwise is intended to be positive and counterclockwise is negative, with the middle of the range being approximately zero or “no weight.” The switches are used to indicate if the input is “on” or not. You may have to experiment with the switches to get them in the right polarity.

There is also an important note on the switch for input 1. You probably noticed that it is a different type of switch. This switch actually has three positions: the center is “off” and when you move the toggle either way, it selects one of two inputs. The first input is the normal input and the second is a feedback signal from the output, which we will talk about later. The third knob is the threshold knob, which — amazingly — sets the threshold of the neuron.

You will want to make sure your potentiometers are connected in the right polarity. You want full counterclockwise to connect the

center lead to the negative supply voltage and clockwise to connect to the positive supply. If you have a multimeter, you can easily verify this by varying the knob and checking the voltage on the center lead. Without using a meter, you will have to experiment a bit.

First (since we are using a dual color LED), if the power switch is on and all battery and power connections are good, the LED should show some color. Next, as a simple test, put all knobs in the middle of the range. Now vary the threshold knob back and forth — it should cause the LED to change between green and red.

Now, set the threshold knob in the middle of its range. Set input switch SW1 to its middle position. Now vary the input 2 knob. If nothing changes, then the input switch SW1 is off. Switch it the other way and vary the knob. If you do not see a change now, then you should go back and check your wiring. Next, turn the input 2 switch back off and try the same thing with input 1. Another thing to check is the polarity of the LED — a positive output is intended to show as green.

The Perceptron can be used to emulate simple Boolean logic gates. First we will try an OR gate, which has a truth table as shown in Figure



■ FIGURE 4. Finished Unit.

5. In Perceptron terms, the output will be on (green) if either input is on. To configure the Perceptron for this operation, set the threshold knob to a little over halfway and each weight knob well over halfway. Now try the switches in different combinations. With either switch on, you should see a strong green light. Now try a NAND gate configuration. For this function, set the threshold knob most of the way counterclockwise and set the weight knobs a little more clockwise than the threshold.

The idea is that the threshold is strongly negative and each weight is

■ FIGURE 5. Boolean Logic Tables.

Truth Table for OR Function

X	Y	A
0	0	0
0	1	1
1	0	1
1	1	1

Truth Table for NAND Function

X	Y	A
0	0	1
0	1	1
1	0	1
1	1	0



somewhat negative. In this way, there will be a positive output unless both inputs are on and combine to drive the sum below the threshold.

A Neural Oscillator

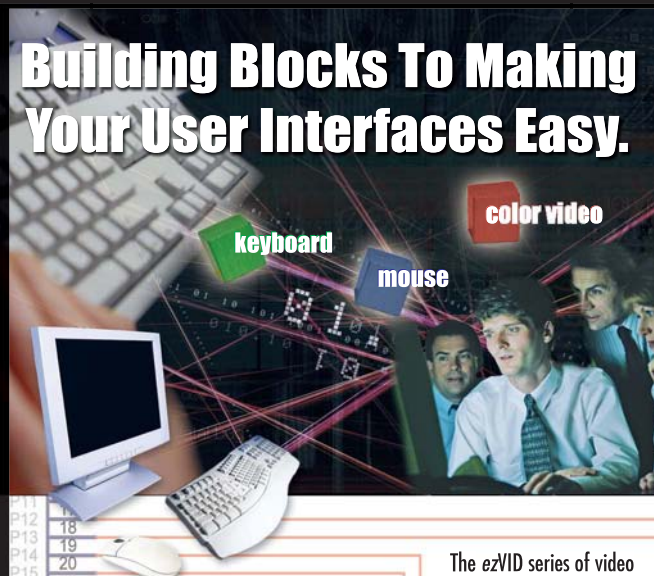
Now, let's talk about the third setting of switch SW1. Our Perceptron is a highly idealized model of a real biological neuron, and it would take some complex electronics to model all of its functions. However, the Perceptron does include one additional behavior, which brings us to an interesting fact — Neuron Property #3.

NEURON PROPERTY #3: A neuron has a built-in time delay.

A neuron's operation is a complex function of time, but for our purposes we will consider a simple time delay. As with all real world devices, a neuron cannot instantaneously produce an output and, in fact, operates quite slowly (on the order of milliseconds) compared to electronic circuits (nanoseconds). But as we will see shortly, time delays are actually useful in the same way that clocking functions are critical to digital circuit operation.

One of the extra amps on the LM324 chip has been used to create a second neuron. This neuron only has a single input which is the output of the first neuron. But it also has a time delay, which is implemented by the combination of C1 and R6. When switch SW1 is moved to its third position, it connects an inverted version of the first neuron's output back as an input to itself. However, because of the delay circuit, this doesn't happen until after about a second. Since the signal is inverted, it causes the first neuron to change its state, and then keep switching back and forth about once a second. The result is a simple oscillator that has been created using only neurons.

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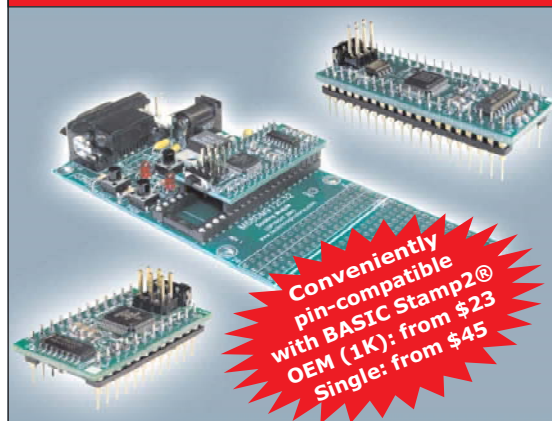
Wrapping Up

If you are new to the concept of neurons and neural networks, the Perceptron offers a practical hands-on introduction to a neuron's operation. If you are a seasoned pro, I think you will find it to be an entertaining diversion that is simple to build, and makes a fun accessory for your desk. **NV**

ABOUT THE AUTHOR

■ Christopher McCarley is currently a software architect at Viziqr Solutions. He has done postgraduate research in VLSI analog neural network design and has 20 years experience developing a variety of technologies including middleware, robotics, and laser systems.

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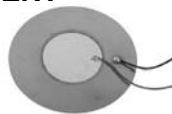
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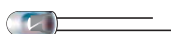


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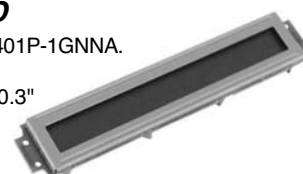
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INNOVATION ROBOTICS UNVEILS ROBOTIC CRANE



Innovation Robotics (www.innovationrobotics.com) unveiled its latest prototype science exhibit last November at the North Carolina Science Teachers Association annual meet at the Koury Convention Center in Greensboro.

The exhibit featured a computer controlled working robotic crane capable of stacking blocks and other items in complex patterns — both vertically and horizontally — completely on its own with no human intervention. The crane can also be operated manually to challenge visitors to use their hand and eye coordination skills to construct creations of their own.

The exhibit demonstrated a variety of scientific principles and hopes to make learning about computers and automation fun. It teaches the principles of the Cartesian coordinate



system while working in a 3D space, as well as the basic principles of automation and robotics.

The new exhibit was joined by another very popular exhibit from Innovation Robotics, the Ring Vortex Generator. The device thrilled visitors of all ages as they marveled at the giant rings of vapor moving across the convention center.

APEC 06 MOVES TO DALLAS; CONFERENCE & EXHIBIT SLATED FOR MARCH 19-23

Hurricane aftermath forces move from New Orleans; 2006 Dallas event promises to be bigger and better than ever

The Applied Power Electronics Conference (APEC), the premier global event in power electronics (www.apec-conf.org), has been rescheduled to the week of March 19-23, 2006 and relocated to the Hyatt Regency Hotel in Dallas, TX. The conference is jointly sponsored by the Institute of Electrical and Electronic Engineers (IEEE) Power Electronics Society (PELS), the IEEE Industry Applications Society (IAS), and the Power Sources Manufacturers Association (PSMA).

"The devastating effect of Hurricane Katrina on the city of New Orleans has made it necessary for the APEC executive steering committee to secure an alternate venue for next year's conference and exhibition," said Kevin Parmenter, publicity chairman for APEC 2006.

"We are truly saddened by the hurricane's devastating impact on New Orleans and the whole gulf coast region. At the same time, we're grateful for the support that the city of Dallas and the Hyatt Regency Dallas have shown in accommodating our conference needs on such short notice," Parmenter added.

"The region's many leading producers, consumers, designers and distributors of power electronic products and components make the Dallas/Ft. Worth area an ideal venue. As in previous shows, this year's event in Austin saw conference participation climb with 328 peer-reviewed papers presented by speakers from 28 countries, a growth trend we fully expect to meet and exceed next year in Dallas," he said.

Now in its 21st year, APEC's continuing popularity is due in large measure to its unique combination of high-quality technical presentations and the collegial, informative atmosphere in which a broad spectrum of manufacturers can exhibit their latest product innovations.

Popular with conference attendees, lively "rap sessions" feature panelists and audience members engaging in lively exchanges about

emerging technologies and often controversial subjects. Another increasingly popular event is APEC's famous annual "Micro Mouse" team competition to design the winning robot that will successfully negotiate the contest maze in the shortest elapsed time.

APEC 2006 conference topics slated for presentation in Dallas will include:

- AC-DC power supplies — single phase and multiphase AC-DC power supplies, power factor correction, multi-level active front end conversion
- DC-DC converters — low voltage to low voltage conversion, high voltage, high power (kW to MW), microprocessor power (VRMs)
- DC-AC inverters — DC to single phase, DC to multiphase, multilevel inverters
- Motor drives for induction machines, permanent magnet machines, switched reluctance machines
- Power semiconductors, energy

storage components, and sensors

- Energy storage components including magnetics, capacitors, batteries and chargers
- Mechanical components including connectors, bus bars, substrates, thermal management
- Physical design and packaging topics including thermal management, integration of design tools, physical design, packaging, EMI, and EMC
- Modeling, simulation and control of power supplies, electric machines and drives, power systems
- Business issues such as marketing, manufacturing, quality, test, power electronics business issues, DFX, standards, and regulations

For more information, editors are invited to contact: Kevin Parmenter, APEC 2006 Publicity Chair, Fairchild Semiconductor, 480-633-5678; Kevin.parmenter@fairchildsemi.com

MOUSER ELECTRONICS BREAKS GROUND ON NEW FACILITY

*Electronics Distributor Plans
402,000 SF Headquarters/
Warehouse Building*

Mouser Electronics, Inc., the fastest growing electronics distributor in the industry, has broken ground on a 229,000 SF expansion of their 173,000 SF Mansfield, TX headquarters facility.

A privately-held company, Mouser Electronics is the fastest growing electronics distributor in North America. A sign of the company's aggressive focus on customer service, Mouser is the only catalog distributor of electronic components to publish a new 1,600+ page print catalog every 90 days. The company's online store at www.mouser.com now offers more than 550,000 products, as well.

Because of Mouser's fast growth and expanding product selection, the company needed to more than

double the size of its existing facility, according to Mouser Electronics President and CEO, Glenn Smith. "We started planning the addition to the facility as soon as we saw that we needed it," he said. "By the time we had the planning and all the approvals in place, we had already grown to the next level."

The addition will add more than 229,000 SF of space to the existing

building. More than 52,000 SF of new office space will accommodate offices, conference and meeting facilities, an expanded customer service call center, and a new data center. The data center will connect to multiple power sources and to three dedicated fiber communications lines to ensure uninterrupted Internet operations, a core component of Mouser's global sales operation. **NV**

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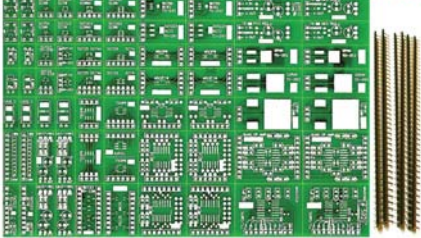


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The little pictures and things take up half the space. There is no need for it!! You have to try and read around the photos. I don't know where you are going but it is in the wrong direction!! I don't really like your thick paper insert but it is the only one.

If you start putting in those cards then you can count me out as a customer. I have enjoyed *NV* over the years. And, for the record, it's the only magazine I get. Please go back to the old format, before November.

Gary Stutts

GONE ASTRAY

I think you folks have really gone astray with your latest issue. I already subscribe to *Popular Science* so I really do not want to see the kind of stuff you put in this last issue.

Take a look at several of your issues from 2001, 2002 (I have been doing just that, today).

Those issues contain real hobby electronics and robotics, I enjoy those

old issues much more than what you put out now.

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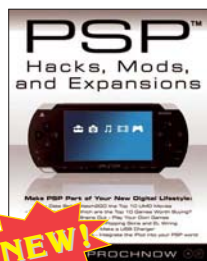


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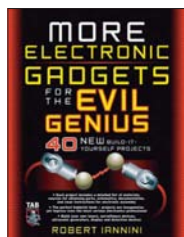
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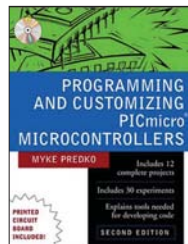


MICROCONTROLLERS

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by Myke Predko

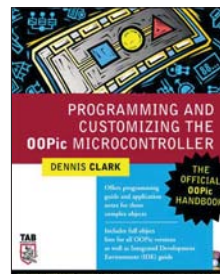
This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICMicros' hardware architecture and software schemes will complement the host of experiments and projects making this a true "learn as you go" tutorial. New sections on basic electronics and basic programming have been added for less sophisticated users, along with 10 new projects and 20 new experiments. The CD-ROM contains all source code presented in the book, software tools designed by Microchip and third party vendors for applications, and the complete data sheets for the PIC family in PDF format. **\$49.95**
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Programming and Customizing the PICAXE Microcontroller

by David Lincoln

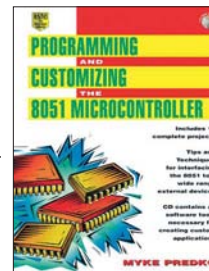
This beginner-friendly guide from IT pro and PICAXE expert, David Lincoln, shows you just what Revolution Education's PICAXE can do — and helps you make it do it! Packed with ready-to-build projects for all the flavors of PICAXE, the guide provides step-by-step help that's ideal for those just starting out with microcontrollers but also takes more experienced programmers where they need to go fast. Using plenty of examples, *Programming and Customizing the PICAXE Microcontroller* clarifies this versatile chip's basics and coaches you through sophisticated applications. **\$39.95**
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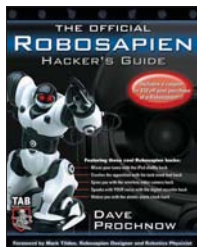
Assuming no prior knowledge of microcontrollers and introducing the PIC Microcontroller's capabilities through simple projects, this book is ideal for electronics hobbyists, students, school pupils, and technicians. The step-by-step explanations and the useful projects make it ideal for student and pupil self-study. The revised third edition focuses entirely on the re-programmable Flash PIC microcontrollers such as the PIC16F54, PIC16F84, and the extraordinary eight-pin PIC12F508 and PIC12F675 devices. **\$26.95**



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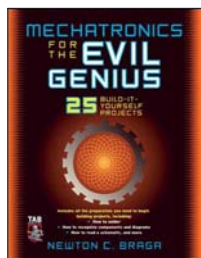
The Official Robosapien Hacker's Guide by Dave Prochnow

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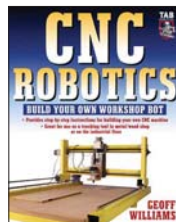
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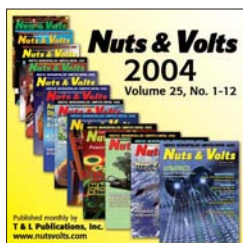
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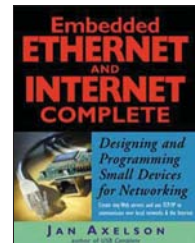
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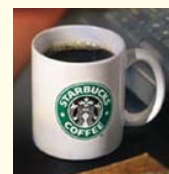
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Analog Music Synthesizers

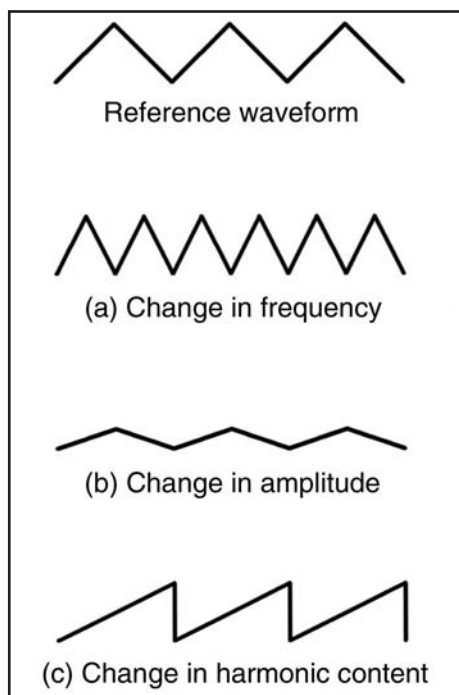
A Do-It-Yourself Primer

b y T h o m a s H e n r y

There is no doubt that synthesizers have changed the face of music over the past 30 years. Synthesizers' initial impact was in the area of "academic" music, since their almost brutish size, extreme complexity, and exorbitant cost fairly much confined them to university settings. But as interested experimenters became more familiar with the concepts of electronic music, and the linear integrated circuit revolution kicked into high gear, homebrew analog synthesizers started to pop up.

And so this versatile instrument made the transition from "new" music to popular music; there's hardly a song on the radio today that doesn't feature it. But literally, it's thanks to thousands of amateurs toiling away in their home workshops and studios that the electronic music synthesizer was propelled into the mainstream.

Would you like to join in on the fun? Well then, the purpose of this article is to explain how you can get started in the fascinating field of electronic music synthesis. As a reader of this magazine, you already have an interest in and knowledge of electronics. But perhaps the principles of electronic music circuitry and what it takes to make a truly useful performance instrument are new to you. This article will help bridge that gap between technology and art.



■ FIGURE 1. Three parameters of sound.

The emphasis here is on learning about **analog** music synthesizers. Not only are their circuits perhaps more accessible to beginners, but they're also imbued with a certain warmth of sound that is unequalled. And lest you think analog technology is too feeble to be useful in this digital day and age, keep in mind that some amazing music, like Walter Carlos' famous *Switched On Bach*, was created

over three decades ago on analog machines far less sophisticated than what you can build yourself today.

If this all sounds exciting to you, then let's tuck in and see how to learn about analog music synthesizers.

THE THREE ASPECTS OF SOUND

Analog music synthesizers depend upon the rather simple concept that any sound (musical or otherwise) can be described by three parameters only: frequency, amplitude, and harmonic content. The basic notion is that if we can analyze a sound into its three constituents, then by reversing the steps we should be able to synthesize it from scratch, as well. Let's look at these three aspects in more detail.

Frequency is a measure of how often a waveform repeats in a given interval. Refer to Figure 1. Comparing the waveform in Part (a) with the reference waveform, we see that it is twice the frequency. In loose terms, the frequency of an audio signal corresponds to what a musician calls pitch. For the two triangle waves illustrated, the second one is an octave higher (twice the frequency) than the reference.

The second parameter of sound is that of amplitude. Again, refer to Figure 1. Here we note that the height of the

waveform in Part (b) is about half that of the reference waveform. If this were an audio signal we were listening to, we'd say that the sound is softer or less loud. Notice in this case that the frequencies of the reference waveform and Part (b) are identical; it's only the amplitudes which differ.

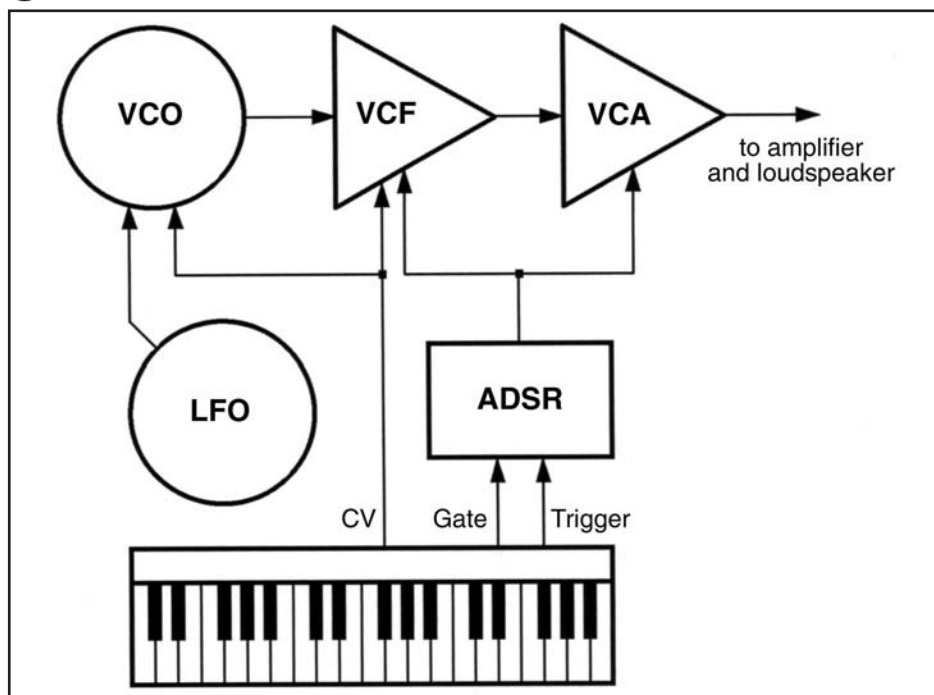
Finally, the third aspect of sound can be referred to as harmonic content. An easy way to understand this is by trying a simple experiment. Sing the following vowel sounds in one long, drawn out phrase, "ooooh ... ahhhh ... eeeee." Slur the sounds together, but don't alter the pitch or volume at which you sing them. Even though you've held two of the parameters fixed, something is obviously changing. This is the harmonic content, called timbre by musicians.

Electronically, it corresponds to an oscillator generating different wave shapes or perhaps a filter modifying those shapes somehow. Refer one final time to Figure 1 and notice how the signal in Part (c) has the same frequency and amplitude as the reference, but the shape is clearly different. By the way, an oscillator that puts out a triangle wave will sound rather pure and flute-like compared to the raspier, violin-like timbre of a ramp wave.

If we can come up with the means to manipulate the frequency, amplitude, and harmonic content of an electronic waveform, then in theory we should be able to synthesize just about any sound we desire. A traditional musical instrument is pretty much stuck in a rut; its ability to change all three parameters is somewhat limited in scope. But with a synthesizer, many more combinations are possible including those never before heard!

WHAT'S INSIDE AN ANALOG SYNTHESIZER?

While the fundamental concept is quite simple, coming up with a complete circuit to usefully manipulate all three parameters of sound can be daunting. The only reasonable way to proceed is by *divide and conquer*. That is, rather than thinking of a synthesizer



■ FIGURE 2. Block diagram of a typical single voice analog synthesizer arrangement.

as a single entity, break it down into logical units or modules. Not only is it easier to design and build this way, but you'll find troubleshooting to be much simpler, as well. And then, of course, there's the business of upgrades. If you should happen to come up with an improvement, it'll be simpler to swap out the old module and replace it, leaving the rest of the instrument intact. So let's think modular.

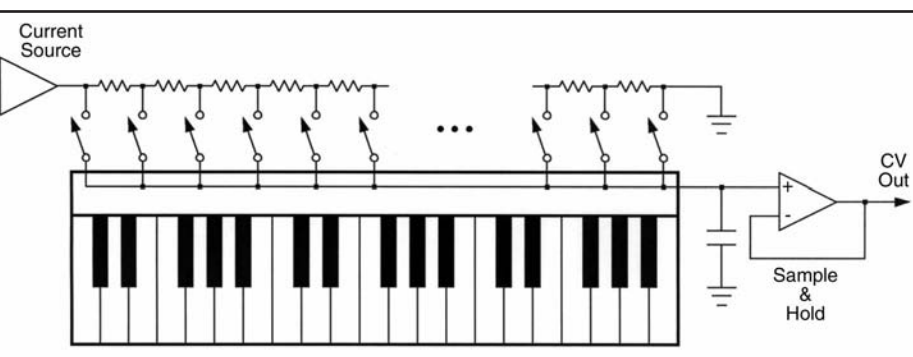
Refer to Figure 2 which shows a block diagram for a typical analog music synthesizer. Don't let the alphabet soup there worry you, for we'll soon sort out what the various acronyms mean. As an overview, let's take a quick run around the figure. Afterwards, we can concentrate on what you should know about the specific modules.

The heart of a synthesizer is the voltage controlled oscillator (VCO) which produces a stable source of waveforms. Voltage control is what makes it so useful, allowing other circuits to easily change its operating frequency. This is a key notion in the design of analog synthesizers.

The control voltage (CV) output of a musical keyboard puts the VCO through its paces. (By the way, in Figure 2, vertical arrows represent control voltages while horizontal ones indicate the audio path.) As you tap out various notes on the keyboard, switch closures are somehow translated into different voltages which causes the VCO to change frequency accordingly. Notice that the VCO can also be modulated by an LFO or low frequency oscillator to impart a vibrato to the waveform, analogous to the effect produced by a violinist wiggling his or her finger against a string being held down.

The audio output of the VCO is routed to the VCF, or voltage controlled filter. The purpose of this module is to modify the harmonic content of the waveform. You'll note one of its control sources comes from the keyboard, too. This is done so that the VCF "tracks," ensuring that the harmonic content doesn't change as we move from note to note, up and down the keyboard.

But most traditional musical instruments do in fact change their timbre over the duration of a single note; think of a how a harmonica player



■ **FIGURE 3. Block diagram of an analog keyboard arrangement.**

cups his or her hands around the instrument to create a "wah-wah" effect. So the VCF is also modulated by an additional control voltage coming from an ADSR envelope generator. More about that module in just a moment.

We've seen so far how the frequency and harmonic content are manipulated in the instrument by the VCO and VCF circuits. The remaining parameter is modulated by the voltage controlled amplifier (VCA). The amplitude of the audio signal passing through it (from the VCF) is boosted or attenuated, once again under control of the ADSR envelope generator. The letters here stand for Attack-Decay-Sustain-Release. These represent the four components making up a cycle of a musical note, beginning from silence, on up to full volume, back down to silence again, and awaiting the start of the next note.

Observe that the keyboard — in addition to putting out the control voltage mentioned earlier — also generates gates and triggers. These two signals tell the ADSR when to do its thing. We'll get more detailed later, but for now just think of the gate and trigger as indicating when a key has been pressed.

Figure 2 has illustrated just one simple "patch." But in a full-fledged analog synthesizer, hundreds, if not thousands of other arrangements are possible. Since each module sports a variety of jacks, one need merely rearrange the interconnecting patch cords to effect a new circuit configuration. Both audio and control voltage interconnections can be made.

MODULES FOR MUSIC SYNTHESIS

With this overview out of the way, we can focus on modules that

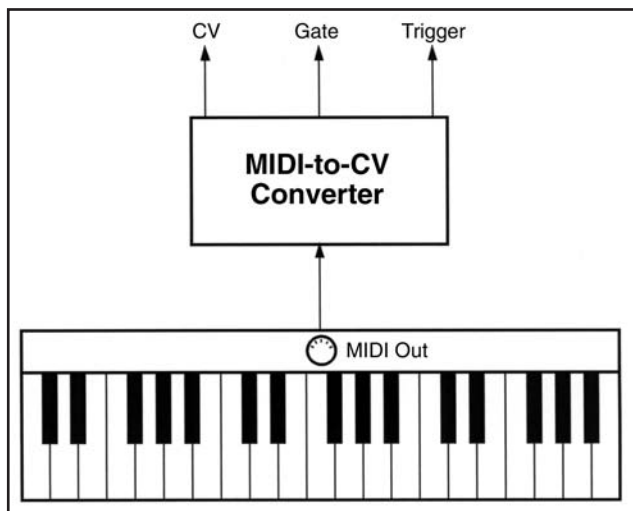
you can easily construct to make a complete analog synthesizer. Let's begin with the keyboard. You have two basic approaches available: analog and an analog/digital hybrid. Take a look at Figure 3 which depicts the former.

A constant current source drives a string of resistors. When a key is depressed, a switch underneath closes, dumping the voltage corresponding to that part of the resistor string onto a bus. Note, then, that each key will produce a different voltage since each one selects a differing number of resistors. The bus carries that voltage on to a sample-and-hold. It's the duty of this circuit to "remember" that voltage until the next key is struck. By the way, the gate and trigger circuitry isn't shown here; typically these are generated with additional switch buses. And if it isn't clear, the focus is on a monophonic system (playing one note at a time); you can worry about polyphony once you get your design chops down!

Such an analog controller interface is quite easy to design and build. The problem is usually finding a raw keyboard sporting a switching bus. Thanks to their popularity in combo organs, 20 years ago these were a dime a dozen, even showing up on the surplus market. Nowadays, however, they're far less common.

But there is a reasonable alternative for our present age. Consider the hybrid arrangement shown in Figure 4. In this case, you use any MIDI enabled unit. Virtually all modern electronic pianos, organs, synthesizers, and so forth come with a MIDI out jack. This even includes most bargain basement synths available at department stores. You simply feed the output





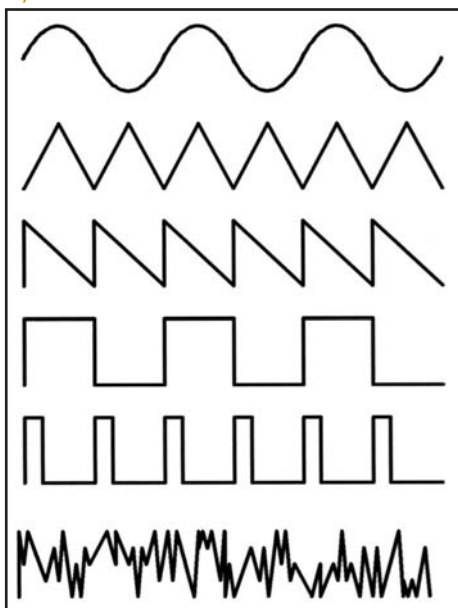
■ **FIGURE 4.** Block diagram of a hybrid keyboard arrangement.

of the keyboard to a MIDI-to-CV converter and take the control voltage, gate, and trigger signals from it instead.

You may protest that the cost or complexity of this hybrid approach is too much to bear. Well, in fact, *Nuts & Volts Magazine* published just such a do-it-yourself version several years ago placing it well within reach of most budgets. See the Resources sidebar for details.

Let's consider the VCO next. A versatile VCO should put out a variety of signals. Refer to Figure 5 which shows some typical synthesizer waveforms. From top-down these are: sine, triangle, ramp, square, and pulse. It's

■ **FIGURE 5.** Some typical analog synthesizer waveforms.



quite straightforward to design oscillator modules to generate all of these, and many different circuits for them have appeared over the years.

The tricky part isn't the output, but what happens at the control voltage input. Most analog music equipment today follows what's called a 1V/octave response. In plain language, each one-volt increment

causes the VCO to double in frequency or to create a sound exactly one octave higher. Due to this doubling phenomenon, the response is, in fact, a base-2 exponential. This is quite different from the linear VCOs you may have seen before. Refer to the table in Figure 6 which compares the responses for two hypothetical units.

One advantage of going with the 1V/octave control input is that the resistors appearing in the keyboard diagram of Figure 3 (or the D-to-A converter implicit in Figure 4) can be equal valued. Pondering Figure 6, you'll soon realize that if you went with a linear response VCO, the resistors would have differing values and probably very non-standard ones at that. In fact, they would all no doubt have to be trimpots just so the thing could be properly tuned to avoid sour notes. Ugh!

By the way, the bottom waveform in Figure 5 is of noise. This isn't created by the VCO, but rather by a separate noise generator circuit. A good noise source is essential in a synthesizer. It can be used to create instrument sounds like drums, hand claps, and



other percussive effects, in addition to nonmusical things like gunshots, explosions, and windstorms.

Voltage controlled filters come in many different flavors. But for most musical work, a four pole lowpass type works well. A number of good designs have appeared over the years using discrete transistors; other versions exploit the CA3080 or LM13700 transconductance op-amps. As mentioned earlier, it's a good thing if the VCF tracks the VCO, so again you'll want to build one which follows the industry standard of 1V/octave.

VCAs are quite a bit easier to design and build, since they're most useful if the control input obeys a simpler linear response. About the only point to look out for is the business of control voltage rejection. There's no need to get real technical here, but essentially a unit with poor control voltage rejection tends to "thump" if it goes from low gain to high gain rapidly. Luckily, this isn't much of a problem nowadays with the ready availability of better linear chips. By the way, voltage controlled amplifiers are generally configured around operational transconductance op-amps such as those mentioned above.

The ADSR module is employed to create envelopes. The envelope is generally imparted to the amplitude (by means of the VCA), but could also modulate either the VCO or VCF for other musical effects. An ADSR is essentially a timing circuit. It accepts two digital signals — the gate and trigger — and generates a (typically) slowly moving control voltage output in response. Front panel potentiometers let you adjust the timing and level of the resulting envelope.

Refer to Figure 7 which shows the relationships among the various signals. Starting from the left, a gate and trigger occur simultaneously in response to a key being depressed. Now the trigger (perhaps 1mS wide) will always be generated when a key is struck; in fact, if you sweep your hand down all the keys of the instrument domino style, you'll

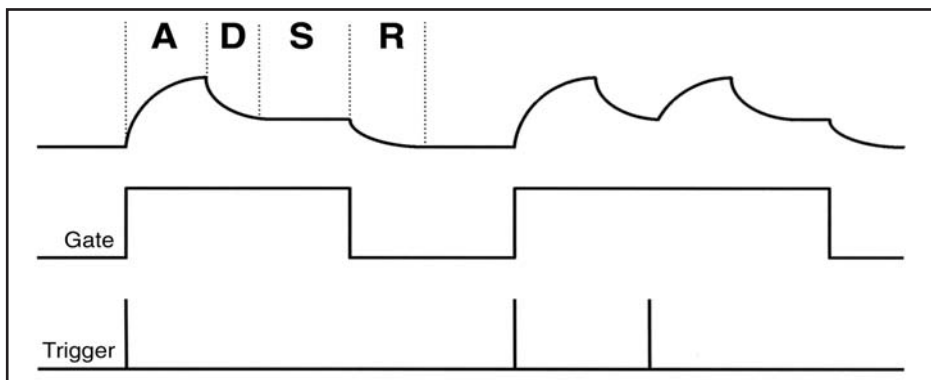
CV	Linear	Exponential
1	100	100
2	200	200
3	300	400
4	400	800
5	500	1,600
6	600	3,200
7	700	6,400
8	800	12,800
9	900	25,600
10	1,000	51,200

■ **FIGURE 6.** The frequency in Hz of a linear VCO increases by a fixed amount for each 1V increment in control voltage. A base-2 exponential VCO doubles in frequency for each step.

■ **FIGURE 7.** Here's the output of an ADSR envelope generator derived from gate and trigger inputs. Notice the righthand portion; although the gate remains steady, a new trigger restarts the attack cycle.

get a trigger for each note. But the gate only lasts as long as a key is *held* in place. The combination of a gate and trigger tells the ADSR to begin its cycle. A capacitor will charge in the usual exponential manner during the attack phase. As mentioned, a front panel potentiometer lets you adjust the amount of time this will take. When it reaches the apex (+5V on most modern synth gear), the decay phase begins. The charge on the cap will bleed off in the amount of time set by a second pot. The voltage will drop to an intermediate level indicated by the sustain pot and remain there as long as the key is still depressed (and the gate is still present).

When the key is finally let go and the gate signal evaporates, the enve-



lope generator enters the release phase. The output voltage will drop at the rate set by yet another front panel potentiometer until it hits zero.

Now consider the right half of Figure 7. It begins the same way, with the attack and decay phases. But notice that a second trigger has come along. In other words, another key has been struck while the first one is still held down. The ADSR enters new attack and decay phases. This is

called retriggering and most musicians deem it a very desirable feature.

ADSRs are extremely easy to design and build. Essentially, all it boils down to is being able to route some currents to and from a timing capacitor at the right moments. There are no critical components, no high frequencies, and no temperature drift to worry about.

As for the LFO, these are even easier to make. The common Schmidt trigger/integrator type of function gen-

RESOURCES

While there are lots of schematics and plans for synthesizer circuits kicking around, many are disappointing. Finding well worked out, high quality designs suitable for a pro quality instrument can be quite a challenge. To point you in the right direction, here are some recommended books, articles, and websites to turn to, broken down by category. A number of the items listed here appeared in *Nuts & Volts Magazine*. If you're missing one, be sure to go to www.nutsvolts.com to locate back issues.

■ Front Panels

Thomas Henry, "Secrets of Making Attractive Rack Panels," *Nuts & Volts Magazine*, December 1998, pp. 72 – 75.

■ Power Supply

Thomas Henry, "Power Supplies for Electronic Music," *Nuts & Volts Magazine*, January 1998, pp. 7 – 11.

■ Keyboard

If you'll be using an analog switching bus keyboard, refer to the first entry below. In any event, Hutchins' collection is essential reading for the serious electronic music synthesizer builder. See the *Electronotes* URL below. The second article shows how to build an inexpensive interface if you'll be taking the MIDI keyboard approach

Bernie Hutchins, *Electronotes Builder's Guide and Preferred Circuits Collection*, (Ithaca, New York: *Electronotes*, 1980), no page numbers shown.

Thomas Henry, "Build Your Own MIDI-to-Synthesizer Interface," *Nuts & Volts Magazine*, December 1997, pp. 52 – 56.

■ VCO

Again, refer to the Hutchins' collection mentioned above for a number of superior VCO designs. For more recent circuits, visit the two websites listed here. Fritz was one of the early guys in electronic music synthesizers and has come up with an extremely precise VCO, giving a detailed analysis of its tuning and temperature characteristics. Ray Wilson's *Music from Outer Space* site is very friendly and chock full of synth circuits and tips. He's even included free printed circuit board artwork for his VCO circuits.

Ian Fritz's Electronic Music Site:
home.earthlink.net/~ijfritz/sy_cir2.htm

Music from Outer Space

www.musicfromouterspace.com/analogsynth/vco.html

■ ADSR

The first design here is one of mine that seems to keep popping up on the Web after two decades, but it's still a good one. The second is an interesting and more modern alternative. Both sites include free downloadable printed circuit board artwork.

A golden oldie

www2.charlielamm.com/synth/adrs.php3

Yves Usson's ADSR

www.timc.imag.fr/Yves.Usson/personnel/SDIY/Modular/EN/ADSR/

■ VCF

Here's Ray Wilson again with an excellent design for a four pole low pass filter. Then the second website shown offers several discrete versions emulating some of the classic VCFs from the past.

Ray Land's VCF

www.musicfromouterspace.com/analogsynth/vcf.html

Synthesizer DIY pages of René Schmitz

www.uni-bonn.de/~uzs159

■ VCA

It's pretty easy to create a high quality VCA using the NE570, CA3080, or LM13700 chips. Here is a good source on how to do it.

Ray Marston, "Understanding and Using OTA Op-Amps," *Nuts & Volts Magazine*, April 2003, pp. 58 – 62, and May 2003, pp. 70 – 74.

■ Noise Generator

Thomas Henry, "Build a Tunable Noise Generator," *Nuts & Volts Magazine*, November 1999, pp. 25 – 27.

The N&V articles, by Thomas Henry, mentioned here are available as PDF downloads from www.nutsvolts.com



■ **FIGURE 8.** Here's a large analog synthesizer built completely from scratch by the author. DIY rack panels serve as faceplates, and the whole thing is housed in homemade rack cabinets made of 1 by 10 lumber.

to find some of the circuit designs mentioned in passing here.

1. Decide on the physical configuration first. For example, you could build your synthesizer in a travel case or make it a desktop unit suitable for studio use. And how about the faceplates? A good choice might be industry standard rack panels. It's not only easy to make handsome ones, but they're physically compatible with most other pro gear. See Figure 8 for an example of what a person can do by hand just in the home workshop.

2. Consider constructing the power supply first. You'll need one in any event, and it's just as well to get this important (if distinctly non-sexy) module out of the way. Plus, you can

use it for testing new circuits as you progress on your system. By the way, it's a smart idea to plan on having +5V and bipolar $\pm 15V$ outputs available. The +5V one is good for TTL and any microprocessors, while the bipolar $\pm 15V$ supply can handle the linear circuitry. And make them with enough "oomph" so you can power up a quantity of modules. A minimum of 500 mA per output would be wise.

3. Take care of the keyboard next. If you can lay your hands on an old switching-bus type of raw keyboard, great. Then you can build the analog style illustrated in Figure 3. In the more likely event you can't locate one, invest in an inexpensive MIDI output keyboard and build a MIDI-to-CV converter as depicted in Figure 4. Even though you don't have any other modules yet, you can still check that its output gives the required IV/octave response using a digital multimeter.

4. Now comes the VCO. In many ways,



erator works very well and is inexpensive. There are other analog synthesizer modules possible, too, but the ones described above will get you started nicely. And since you're going modular, you can always add, subtract, or swap later on!

BUILDING A SYNTH — FIRST STEPS

If you've got a feel for what you'd like your system to have, then here's a suggested plan of attack. Remember, the Resources sidebar indicates where

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this will be the most sophisticated circuit in your synthesizer, so first spend some time looking over the various options pointed out in the Resources sidebar. Decide if you'll go with an expensive "one-chip" type of music VCO or a more traditional approach. When you complete construction of the VCO, you can test it with the power supply and keyboard interface finished previously. You won't have any control over the envelope yet, so it'll just squawk at you full volume like an organ, but at least you can check its tuning accuracy.

5. Next, consider building the ADSR. This should be a quick, one-weekend project. If you like, you can test it roughly on an oscilloscope or even an analog voltmeter. Patch in the gate and trigger signals from the keyboard and monitor the ADSR's output. As you depress a key you'll be able to follow the changes in output voltage, and see the timing effects of the various pots.

6. Then continue on to the VCA. After wrapping up this module, you'll finally be able to hear some truly musical results. Patch the VCO to the audio input of the VCA, and the ADSR to the control voltage input. Now when you play some notes on the keyboard, it'll seem like a real instrument. It's the variable amplitude envelope that makes the unit much more than just a simple organ.

7. The VCF comes next. There are so many types to choose from, you probably ought to spend some time poring over the literature first. As mentioned, the four pole low pass VCF is a good choice, but don't hesitate to try something simpler just to get going. Even the humblest of filters when patched into the audio chain begins to give you some remarkable sounds.

8. If you'd like, try your hand at an LFO and then a noise generator. The tunable noise generator which was published in *Nuts & Volts* previously is particularly effective, and yet is inexpensive and easy to build.

At this point you'll have a good basic system in place to form the foun-

dation of an even more complex instrument; it'll be easy to add on new modules as you design and build them. And the pride you'll feel performing on a synthesizer you've constructed with your own two hands is immense. But most importantly, if you've made it this far, then you will have started to really learn the ins and outs of electronic music synthesizer design — one of the most exciting and fascinating aspects of hobby electronics! **NV**

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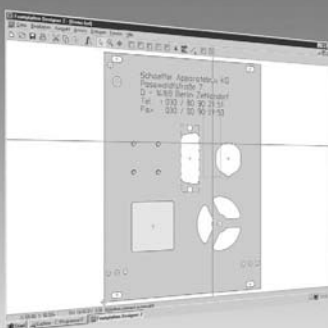
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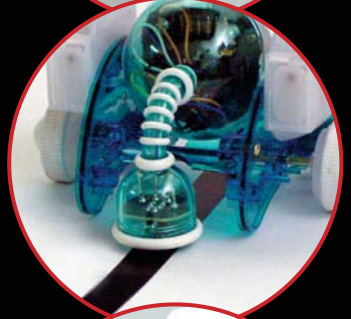
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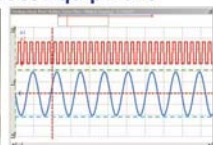
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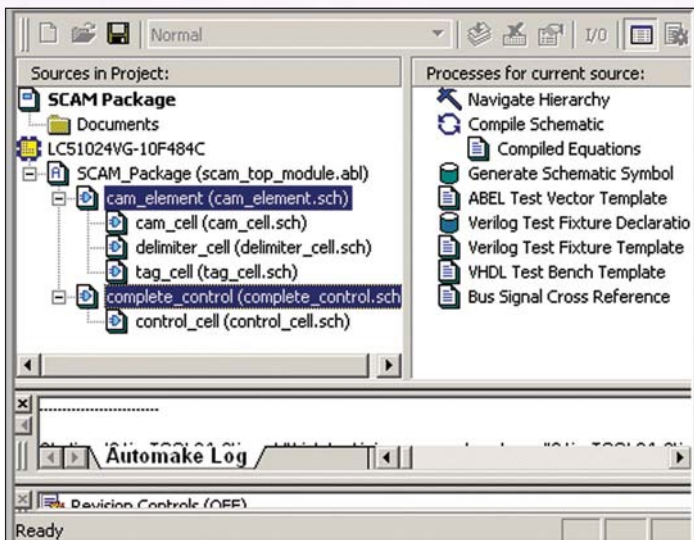
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DATA Processing Using SCAM⁽⁴⁾

IMPLEMENTING SCAM: Building the SCAM Basic Blocks

SCAM HIERARCHICAL DESIGN REALIZATION

The SCAM is composed of three main blocks: the



In this article, I present the logic circuit design of the building blocks of the SCAM device using ispLEVER professional design tools.



controller (SCAMC), the data repository (SCAMD), and the response block (SCAMR), as described in the first article of this series.

In order to realize my design, I used ispLEVER Schematic Editor to prepare the logic circuit schematics for the building blocks of the SCAM. The process started with designing the basic cell types representing the bottom of the hierarchy. Figure 1 illustrates those hierarchy cells denoted by "cam_cell," "delimiter_cell," "tag_cell," and "control_cell." A symbol (representing a virtual logic device) was created for each cell type using the ispLEVER Project Navigator process, "Generate Symbolic Symbol" (see the right pane in Figure 1).

The next level of the hierarchy is a compilation of those cell types into blocks of cells. I used those symbols to create a 10-bit SCAMC block named "complete_control," representing the SCAMC. I also produced "cam_element," representing a complete data word composed of a

SCAMD and SCAMR string of

B y G a m a l A l i L a b i b

■ **Table 1. Input Signals Legend for the SCAM Chip Building Blocks.**

eight bits of data, one Structure cell, one Element cell, and one Tag cell.

In order to build a SCAM device, I used the ABEL language to assemble SCAM blocks with multiple data words to form the final device. The next and final article will discuss the ABEL module in detail.

SCHEMATIC MODULES

Included here are four schematics of the logic circuits of the control cell, the element delimiter cell, the structure and data cells, and the tag cell. Tables 1 and 2 describe the input and output signals of each schematic.

Figure 2 shows the control cell logic. It is composed of one flip-flop for a Mask bit (denoted by I12) and another for a Comparand bit (denoted by I13). Data input to either flip-flop is controlled by "SM," "SC" signals. Masked Comparand data appears as signal "C" and negated as "Cn." Those signals are passed on to all data bits in the SCAMD block for comparison with data stored in the block. The Mask, Comparand, and data propagated from other SCAM devices ("READi" signal) are passed on, as well as "READo." The symbol for the SCAMC block cell is shown in Figure 3, while the complete block symbol is shown in Figure 4.

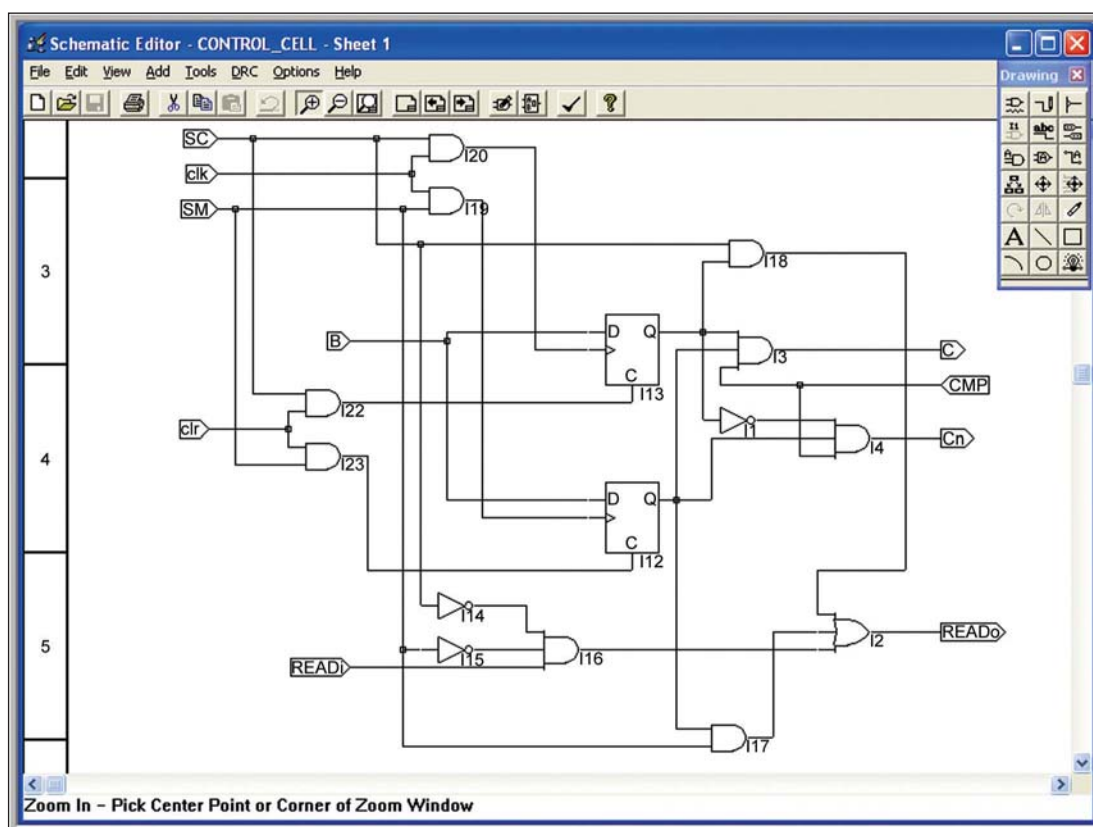
Figure 5 shows the logic circuit of an Element delimiter cell. It is

Signal	Description	External	Internal
SC	Forward input from the data bus to Comparand cells of this bit slice	√	--
clk	Master SCAM module clock	√	--
SM	Forward input from the data bus to Mask cells of this bit slice	√	--
D, Di	Input from computer data bus to SCAMC module	√	--
B	Input from computer data bus to control cell symbol	√	--
CMP	Compare Command signal	√	--
clr	Clear Command signal to all cells in the SCAMC	√	--
READi	Aggregated state of this bit slice from previous SCAM module or from previous words in current SCAM module	√	√
WS	Word Select signal from Tag cell to each delimiter and Data cell of this word	--	√
RESULTi	Accumulated state output of Tag cells of previous words propagated to next word	√	√
QEI	Inverted state of Element delimiter cell input to Tag cell of current word	--	√
ST	Forward input from the data bus to Tag cells	√	--
FSETi	Realizes forward navigation in conjunction with LNW. Sets Tag cell of next word to 1 if current Tag is set to 1 [operating in Parallel Mode (MODE=1) or current Tag is the top most set cell]	√	√
BSETi	Realizes backward navigation in conjunction with LPW. Sets Tag cell of previous word to 1 if current Tag is set to 1 [operating in Parallel Mode (MODE=1) or current Tag is the top most set cell]	√	√
LNE	Link activity to next element	√	--
QFi	State of forward navigation line of current word linked to next word and is used to link activity to the next element delimiter word. It is disabled if current word is an element delimiter word	√	√
QBi	State of backward navigation line of current word linked to previous word and is used to link activity to the current element delimiter word. It is disabled if current word is an element delimiter word	√	√
LPE	Link activity to previous element	√	--
SET	Set all Tag bits to 1	√	--
MODE	1=Operate on all SCAM words in parallel 0=Operate on currently selected word only	√	--
NSi	1=No matching found in previous words 0=At least one matching word found in previous words	√	√
LNW	Link activity to next word	√	--
LPW	Link activity to previous word	√	--
Mismatchi	Accumulated Mismatch results of previous bits to this bit in current word	--	√
C, Cn	Masked Comparand cell state outputs to this bit slice of the SCAMD [0,0] No comparison in this bit slice is done [0,1] Compare cells in this bit slice with 1 [1,0] Compare cells in this bit slice with 0	--	√

Signal	Description	External	Internal
NSo	1=No matching word found in previous words' Tag cells 0=At least one matching word found in previous words' Tag cells	✓	✓
QBo	State of backward navigation line of current word linked to previous word, and is used to link activity to the current element delimiter word. It is disabled if current word is an element delimiter word	✓	✓
WS	Word Select signal out of the Tag cell to each delimiter and Data cell of this word	--	✓
QFo	State of forward navigation line of current word linked to next word, and is used to link activity to the next element delimiter word. It is disabled if current word is an element delimiter word	✓	✓
FSETo	Realizes forward navigation in conjunction with LNW. Sets Tag cell of next word to 1 if current Tag is set to 1 [operating in Parallel Mode (MODE=1) or current Tag is the top most set cell]	✓	✓
BSETo	Realizes backward navigation in conjunction with LPW. Sets Tag cell of previous word to 1 if current Tag is set to 1 [operating in Parallel Mode (MODE=1) or current Tag is the top most set cell]	✓	✓
C, Cn	Masked Comparand cell state outputs of this bit slice of the SCAMC [0,0] No comparison in this bit slice is done [0,1] Compare cells in this bit slice with 1 [1,0] Compare cells in this bit slice with 0	--	✓
READo	Aggregated state of this bit slice from SCAMC to the first word in SCAMD or to next SCAM module or to next words in current SCAM module	✓	✓
Mismatcho	Accumulated Mismatch results out of this bit in current word	--	✓
QEn	Inverted state of Element delimiter cell of current word	--	✓

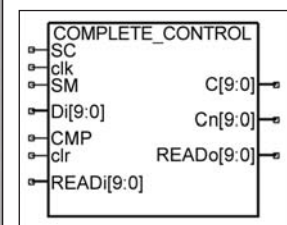
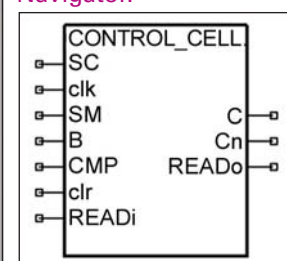
■ **Table 2. Output Signals Legend for the SCAM Chip Building Blocks.**

comprised of a single flip-flop and a few gates for matching its state with the masked Comparand. The result of the matching is passed on via "Mismatcho" to the next cell in the data word. The negated state of this cell, "QEn," is passed on to the Tag cell of the same word to control information propagating from the next word or from the previous word through an Element delimiter word. The symbol for the Element delimiter cell is shown in Figure 6. Figure 7 shows the logic circuit of Structure and Data cells. Its design is similar to that of the Element delimiter cell and adds some logic for passing on the accumulated matching result "Mismatchi" of previous cells in the data word to the following cell (signal



■ **FIGURE 2. Control Cell schematic generated by ispLEVER Schematic Editor.**

■ **FIGURE 3. Control Cell symbol generated by ispLEVER Project Navigator.**

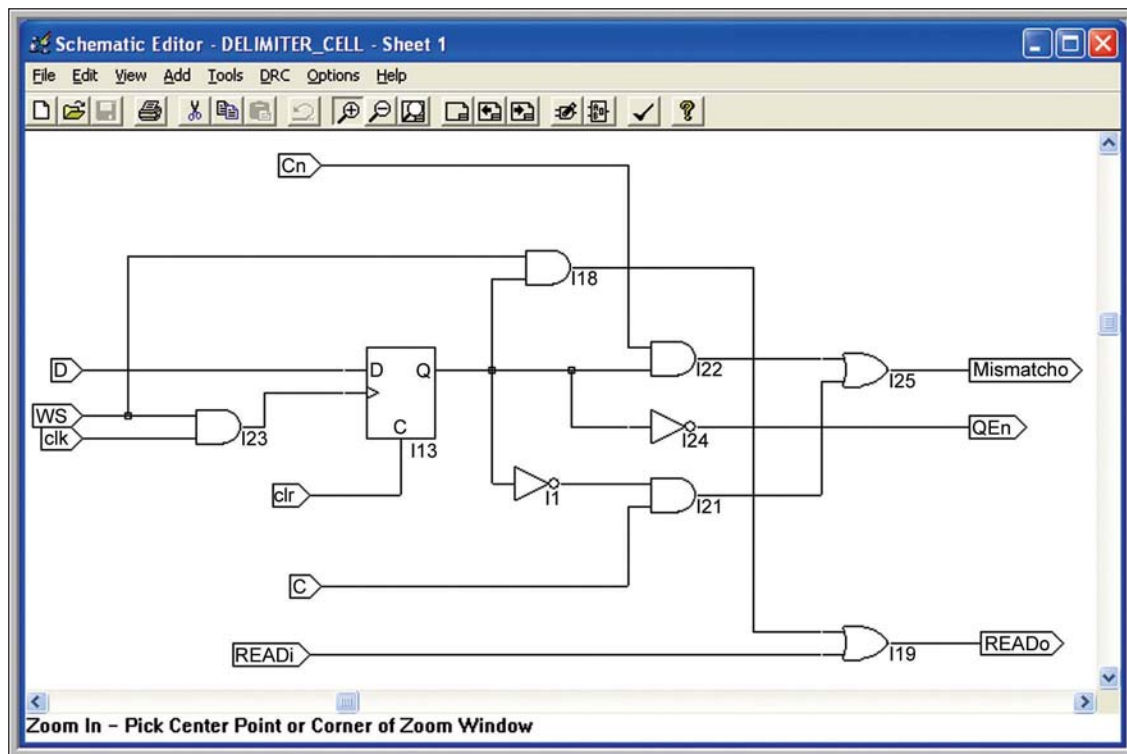


■ **FIGURE 4. 10-Bit SCAM Controller symbol generated by ispLEVER Project Navigator.**

■ **FIGURE 5.** Element Delimiter Cell schematic generated by ispLEVER Schematic Editor.

"Mismatcho"). The symbol for Structure and Data cells is shown in Figure 8.

Figure 9 shows the logic circuit of the Tag cells. This is the most complicated cell type in the SCAM, since it controls navigation within the SCAM and it collects the final matching result of the data word and passes it on to the next and previous words' Tags. Input signal "QEn" represents the "QEn" signal of the Element delimiter cell that controls navigation in the SCAM. "FSETo, QFo" and "BSETo, QBo" represent the propagated accumulated state of the previous and the next Tag cells ("QBi," "QFi") to the next and the previous Tags respectively, upon activating the navigation signals "LNW" and "LPW." The symbol for Tag cells is

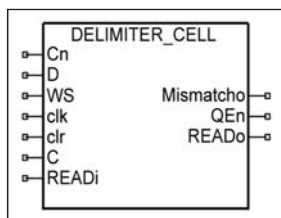


shown in Figure 10.

Finally, we assemble the previous data word cells into a data word, as depicted in Figure 11. It is clear at this stage that using virtual symbols for cell types makes it easier to concatenate 11 cells altogether in a single schematic sheet. Creating a symbol for the data word

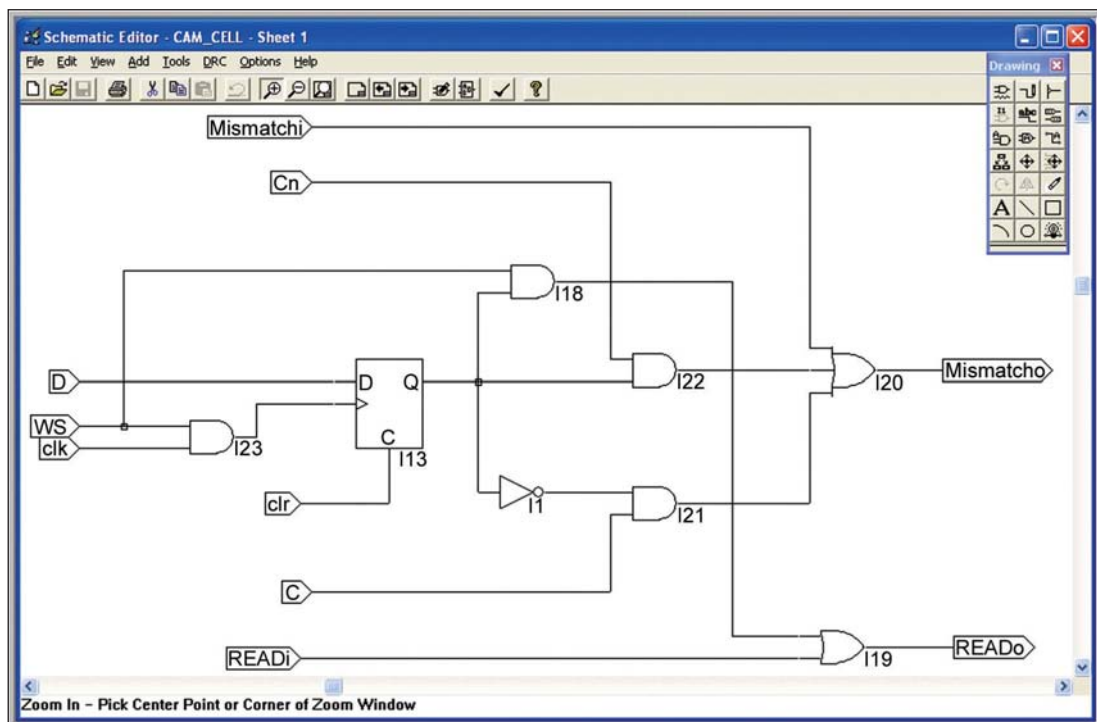
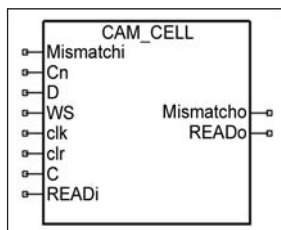
(see Figure 12) is be our last step in building schematics hierarchy. Next month, I will demonstrate the fruitfulness of this symbol in replicating data words to the required SCAM capacity. **NV**

■ **FIGURE 7.** Structure and Data Cell schematic generated by ispLEVER Schematic Editor.



■ **FIGURE 6.** Element Delimiter Cell symbol generated by ispLEVER Project Navigator.

■ **FIGURE 8.** Structure and Data Cell symbol generated by ispLEVER Project Navigator.



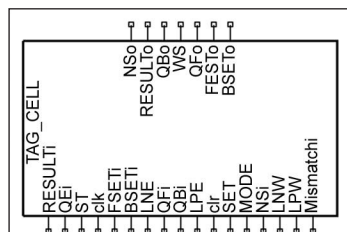
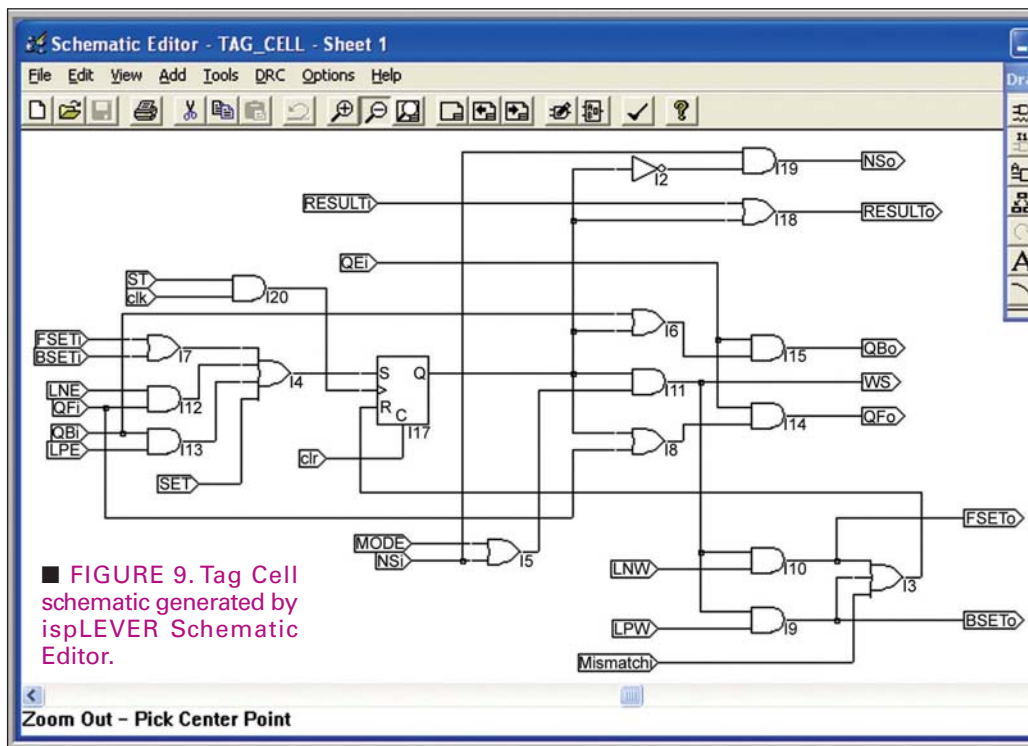


FIGURE 10. Tag Cell symbol generated by ispLEVER Project Navigator.

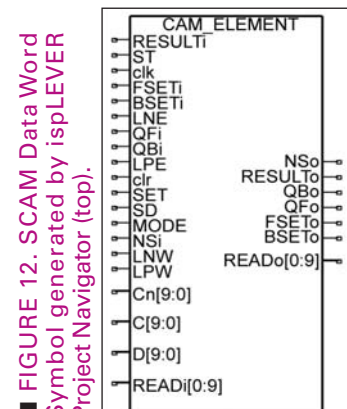
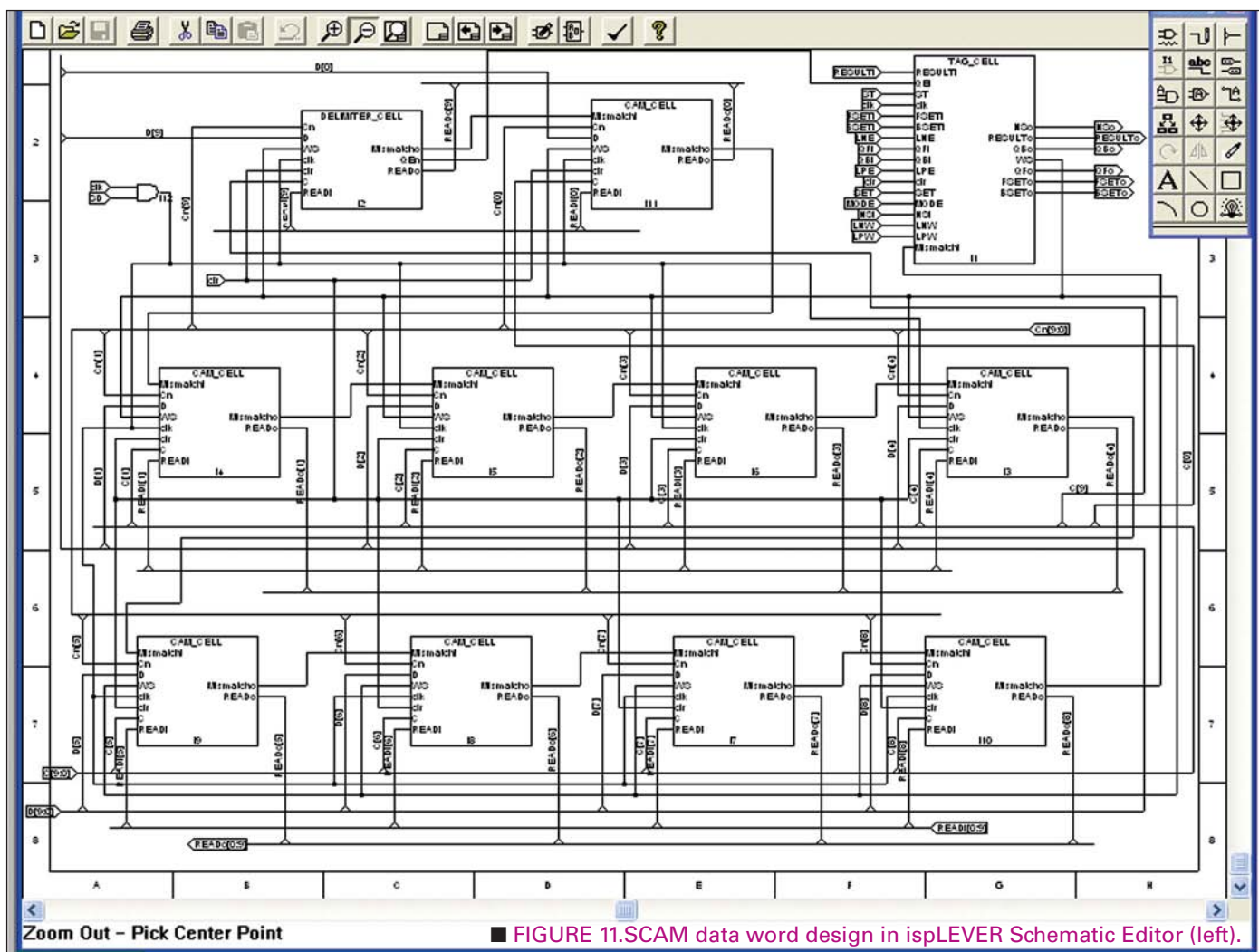


FIGURE 12. SCAM Data Word Symbol generated by ispLEVER Project Navigator (top).



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Getting Started With

PICs

⇒ **A Primer for Beginners**

by **Chuck Hellebuyck**

⇒ **BACKGROUND**

I've written several articles about PICs and even published my book *Programming PIC Microcontrollers With PicBasic*. Feedback has been tremendous. Many readers have thanked me for helping them get started programming PICs with PicBasic. I also get many readers that were old TTL hardware guys left behind by the micro-age and my book/articles helped them get back in the game.

A third category of feedback involves readers that have little or no electronics background and with all the different programmers, compilers, microcontroller choices, software options, etc., they are confused and afraid they would waste a bunch of money and still not get what they want. I'm here to tell you it isn't that difficult and it doesn't have to cost that much to get started.

Microchip PICs have invaded most of the electronic design going on in the world. The best part is, as hobbyists and part time professionals (working from your basement lab), we have access to all the tools we need to create the designs our creative minds come up with.

Through a series of articles, I hope to pass on Microchip PIC design notes that will help you learn electronic design. By focusing on Microchip PICs for the hardware core and Basic Compilers for the software core with some assembly inserted here and there, I hope to get more people involved and having fun.

In this article though, I'm going to focus on the beginner and start off by showing how to put together your own complete Microchip PIC development set-up for under \$50. Let's first cover the basics.

WHAT IS A MICROCHIP PIC AND HOW DOES IT WORK?

Microchip is a company that manufactures microcontrollers and other



⇐ **FIGURE 1.**
16F876A Microchip
PIC Microcontroller.

electronic components. They created a family of eight-bit microcontrollers and called them PICs (some say short for Peripheral Interface Controller). These PICs could be programmed to perform an infinite amount of functions but you might be asking, "What is a microcontroller?"

Everybody reading this has probably used a computer run by a microprocessor. The PC's central microprocessor has several support items that allow it to function. First is the memory, where programs are stored, also known as a hard-drive or ROM. Second is the RAM, or temporary memory, used by programs running in the PC's microprocessor. And third, the interface to the outside world, through input and output ports also known as the BIOS (Basic Input Output System) or I/O.

Through the I/O, the PC sends information to be displayed on the screen you read, or the printer you might send documents to. The I/O also reads the keyboard and mouse position. Basically,

everything the PC does with a useful purpose to humans runs through the I/O. What if you could shrink all those components: microprocessor, ROM, RAM, and I/O, into a single integrated circuit? It can be done and it's called a microcontroller (Figure 1).

There are various companies that make these small microcontrollers and each has a unique personality. Microchip PICs are, in my opinion, the best in the business but don't just take my word for it. Microchip has become the number 1 seller of eight-bit microcontrollers in the world. Microchip did this by offering a whole family of PICs with various I/O features that industry wanted.

The best part is you can use Microchip PICs the same way industry does without laying out a load of money. All you need is software for the PC to write the binary code and a means to burn that code into the PIC. A popular version of the PICs is the 16F876A shown in Figure 1. These can be purchased from various sources for under \$10.

HOW DOES A PIC WORK?

A microcontroller or PIC requires a series of coded electrical signals in its ROM to tell it what to do. This is known as software or code. When a microcontroller is said to be programmed or have code burned into it, it is getting these coded electrical signals stored into its ROM. To run the program, the microcontroller then needs a way to select each command from ROM, one at a time, which is known as running a program.

The microcontroller has a clock oscillator, controlled by an external crystal or resonator, which sends a continuous pulse to the microcontroller's central circuitry when it is powered up. It's like the heart of the microcontroller sending clock signals that control all functions, similar to the way our heart pulses our blood through our body making all our functions work. On each pulse of the clock, the PIC retrieves a new command code from ROM to execute on the PIC I/O. These coded electrical signals are in the format of 1s (five volts) and 0s (ground) or binary code.

By arranging these binary codes

properly, you can make the PIC's I/O turn on and off to control electrical circuitry connected to the PIC's I/O pins. That circuitry could be a simple relay that turns a light on during the night and off during the day. It could be more complex and control the motors of a robot while reading an obstacle sensor to make the robot drive around a maze. All you need to do is write this series of binary code, which is the software.

BASIC COMPILER

Arranging 1s and 0s properly was made easier by the development of assembly language. Microchip developed an assembly language for the PIC that is a series of crude acronyms, each with a specific task. The acronyms are converted into the 1s and 0s by means of a PC software program called an assembler. Even though this is easier than coding directly in 1s and 0s, it's still very cryptic. To resolve that problem, several companies developed higher-level languages that use easy-to-understand words. Each of the words represent a function and are converted into assembly language.

When these higher-level programs are converted into assembly language, they are said to be "compiled." There are several different compilers out there with names such as "C" language or Java language and my favorite, Basic.

The PicBasic Pro compiler (Figure 2) is very easy to use and a great language for someone just getting started. It uses the same format as the popular BASIC Stamp modules but produces a binary file so you can program blank, lower cost PICs.

The PicBasic Pro compiler has advanced over the years to become just as powerful as any other "professional" compiler. You can download a free sample version of the PicBasic Pro compiler, which is more powerful than you might think.

PIC PROGRAMMER

Okay, we've now covered what a Microchip PIC is.

⇒ FIGURE 2.
PicBasic Pro
Basic Compiler.



We know what it takes to develop the software. But how do we get the code (1s and 0s) into the PIC? We do that with a PIC programmer.

A PIC programmer is a custom designed module that generates the electrical signals the PIC's ROM memory requires. The programmer stores these signals, in proper order, in the Microchip PIC. The PIC programmer requires software for the PC that will take the compiled/assembled file of 1s and 0s and send it out the PC's serial port to the PIC programmer.

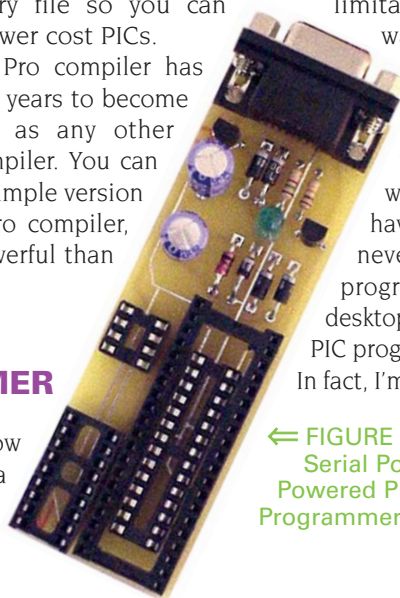
Figure 3 shows my version of an extremely low cost serial port powered PIC programmer based on the JDM Programmer hardware design at www.jdm.homepage.dk/newpics.htm. You don't have to rely on my programmer, either. There are other JDM style programmers available from various sources. Do a Google search and you'll find several. This programmer is driven with the "free" software developed by Bonny Gijzen that you can download at www.ic-prog.com.

Because this programmer is serial port powered, it doesn't work with most laptop computers because the serial port voltage levels are lower on many laptops. It also won't work with USB to RS232 adapters. Despite these

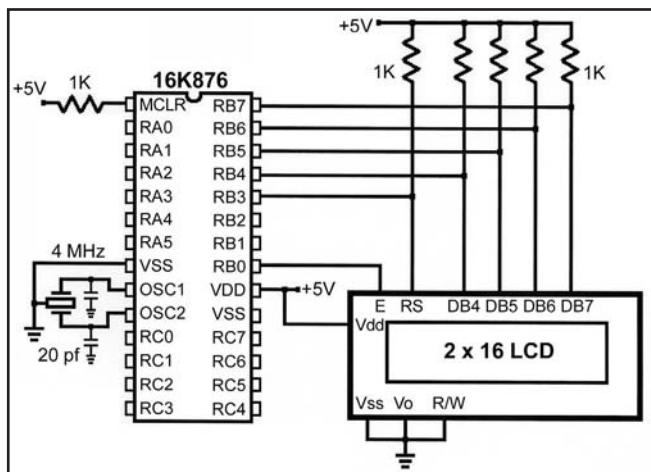
limitations and the free software, you would be amazed at how reliable this JDM style programmer is.

Bonny Gijzen has kept the software updated to work with the latest PICs. I have used it for over a year and never once had a problem programming a PIC from my desktop computer. This is a great PIC programmer design to start with. In fact, I'm turning my design into a kit form so the hobbyist

⇐ FIGURE 3.
Serial Port
Powered PIC
Programmers.



can solder it together as a first project and then use it for all future



← FIGURE 4. Hardware Schematic.

are all supported. This gives you plenty of PICs to work with.

The serial port PIC programmer shown in Figure 3 can be obtained from my website for \$24.95. The kit form will be cheaper and hopefully available by the time you read this at elproducts.com

I also recommend the Microcode Studio IDE software from www.mecanique.co.uk/code-studio. It's also a free download and was designed to work with the PicBasic Pro compiler. It makes writing PicBasic code so much easier. You also will need a few minor components to make the PIC run, such as the clock resonator mentioned earlier and you will need some type of 5V power source along with a few resistors. This can all be built on a standard breadboard.

Since I stated all this could be done for less than \$50 and we've designated \$10 for the PIC and \$25 for the programmer, you have \$15 for the breadboard, wiring, and other components. Not bad right?

PIC projects. You can later upgrade to various professional programmers that will work on a laptop or USB port.

SO WHAT DOES ALL THIS COST?

This is where you might be shocked. A 16F876A Microchip PIC will cost around \$10. The PicBasic Pro compiler shown in Figure 2 comes in a limited sample version that can be downloaded for free from www.melabs.com. It is limited to 31 command lines, but that is more than enough to get started. It is also limited to certain Microchip PICs: 16F627(A), 16F628(A), 16F84(A), 16F870, 16F871, 16F872, 16F873(A), 16F874(A), 16F876(A), and 16F877(A).

31 COMMANDS! WHAT CAN I DO WITH THAT?

You may be wondering, what good is all this if you only get 31 commands to work with? The PicBasic Pro compiler is so efficient to write code with, you really can do many simple home projects with a single PIC chip and less than 31 lines of code.

For example, I'll build a simple LCD controller out of a 16F876A PIC chip. It will simply display the message "Hello World" but can be expanded in the future and still use the sample version of the PicBasic Pro compiler because I'll do this with far less than 31 commands.

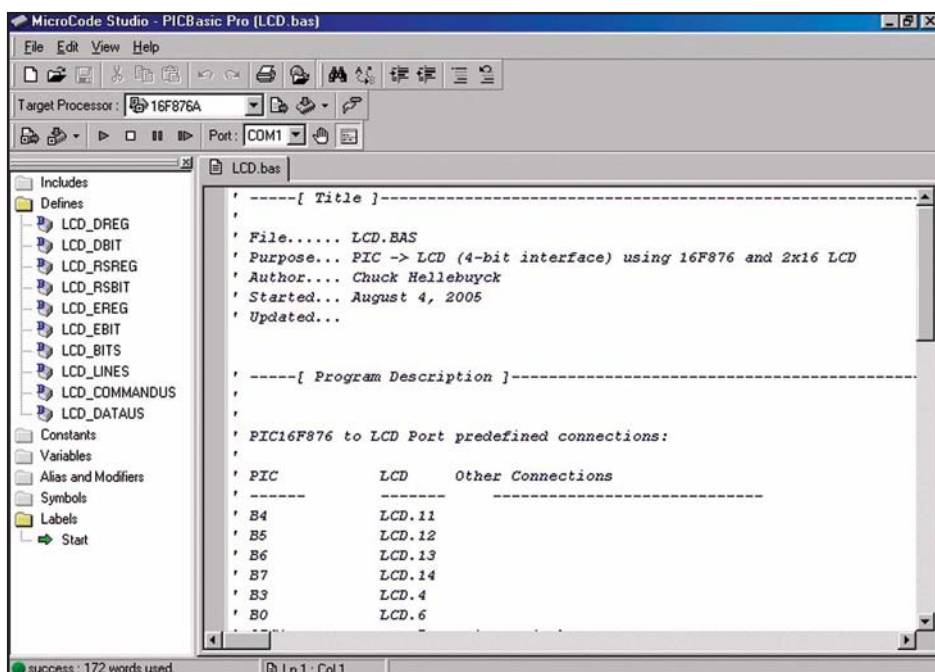
To do this, first download all the free software and install the Microcode Studio software and link it to the PicBasic Pro compiler. You'll have to follow the MCStudio instructions, but in most cases, it will find the PicBasic Pro compiler automatically when you install it. After these steps, you are ready to program your first PIC.

The project schematic is shown in Figure 4. All the connections are straightforward. The PIC 16F876A has a 4 MHz resonator connected to the OSC1 and OSC2 pins. Two 20 pF capacitors are connected to the OSC1 and OSC2 pins to ground. You can get a 4 MHz resonator with the capacitors built in from companies like Digi-Key. The PIC also needs a 1K resistor connected from 5V to the MCLR pin. The MCLR pin is the reset pin so you want this tied high. Pulling this low will reset the PIC, so adding a momentary push button from MCLR to ground is an optional.

The LCD is a parallel version with a Hitachi 44870 driver chip inside. This is a common LCD available all over the place for under \$15 and usually less than \$10. Connect the LCD per the schematic including the 1K pull-up resistors to 5V. These help guarantee a proper voltage level between the PIC and the LCD. After this, the project is ready to be programmed. The hardware is shown assembled in Figure 7.

SOFTWARE

The software is quite easy to



← FIGURE 5. Microcode Studio Window with Software.

understand. Just type the code shown in the code listing into the MicroCode Studio editor window as shown in Figure 5 and save it as LCD.bas. (The LCD.bas code listing is available on the *Nuts & Volts* website; www.nutsvolts.com) After saving it, verify that the little window in the MCStudio screen shows the 16F876A PIC. If not, select it from the list. Now click on the compile icon or just press F9. The program will be compiled and assembled into a file named LCD.hex. Find that file on your hard drive because we need it for the next step.

HOW IT WORKS

The beginning of the code listing shows a list of DEFINES. These set up the LCD connections and establish the communication. There are default values for these which define the connections to the LCD using PortA. Using the default connections would reduce the lines of code counted in the 31 limit because we could skip these definitions. I decided to use them for now, but in future LCD projects, I'll rewire it to save code space (see Listing 1).

The main loop of code is below the "Main Code" title block (see Listing 2).

We have to slow down the PIC by pausing 250 milliseconds. This allows the LCD to get ready to receive command data. Some LCDs need this, others don't. After the pause, the LCDOUT command sends command control data to the LCD. Sending the "\$FE" first tells the LCD to accept the next value as a command code. The "1" is the command code to clear the LCD screen. The "2" is the command code to position the LCD prompt at the first line, first character position. This sets up the LCD to receive the data we want to display.

The following LCDOUT command sends the letters between quotes (Hello World) as ASCII characters to the LCD. The LCD will immediately display that data as "Hello World" starting at the first character block. The program then pauses for one second (PAUSE 1000) and finally

Listing 1:

```
DEFINE LCD_DREG      PORTB  'Define PIC port used for LCD Data lines
DEFINE LCD_DBIT      4      'Define first pin of portb connected to LCD DB4
DEFINE LCD_RSREG     PORTB  'Define PIC port used for RS line of LCD
DEFINE LCD_RSBIT     3      'Define Portb pin used for RS connection
DEFINE LCD_EREG      PORTB  'Define PIC port used for E line of LCD
DEFINE LCD_EBIT      0      'Define PortB pin used for E connection
DEFINE LCD_BITS      4      'Define the 4 bit communication mode to LCD
DEFINE LCD_LINES     2      'Define using a 2 line LCD
DEFINE LCD_COMMANDUS 2000   'Define delay time between sending LCD commands
DEFINE LCD_DATAUS    50     'Define delay time between data sent.
```

Listing 2:

```
          Pause 250              ' Delay for LCD to power up

Start:
  lcdout $fe, 1                 ' Clear LCD
  lcdout $fe, 2                 ' Position cursor at home

***** Send "Hello World" to first line of LCD *****

  lcdout "Hello World"         ' Send "Hello World" to the LCD
```

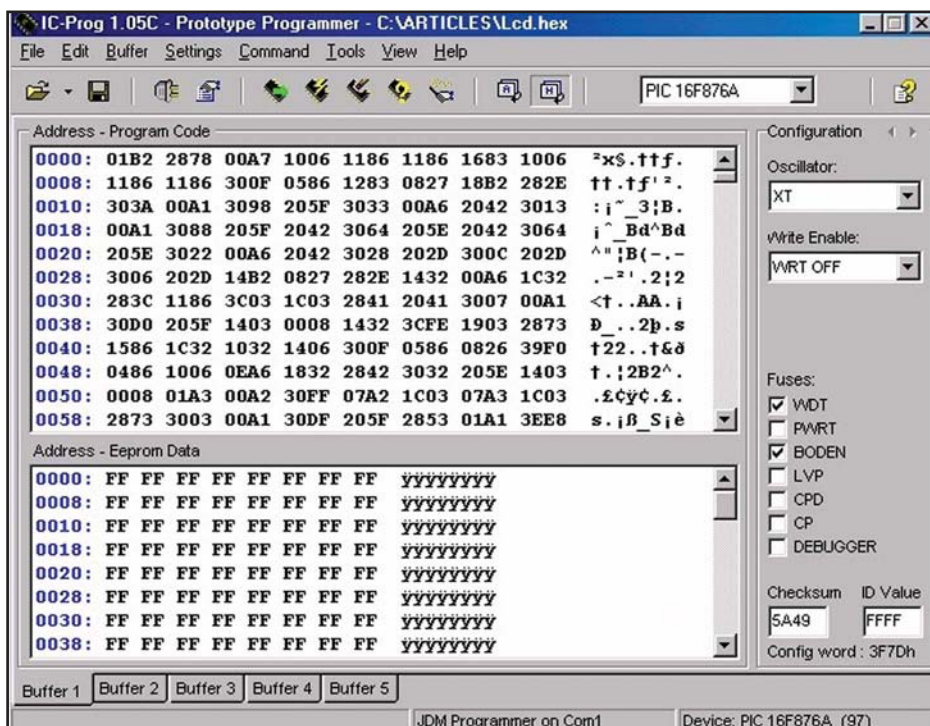
jumps back to the "start" label using the "Goto Start" command line and repeats the process.

Notice we did all that in three main LCDOUT commands, but the DEFINES at the top along with the "Start" label, PAUSEs, and GOTO commands all count toward the 31 limit. As written, this program uses 17 command lines leaving 14 for additional commands or labels. Variables do not count towards the 31 so there are more things we can do with 31 total commands. As

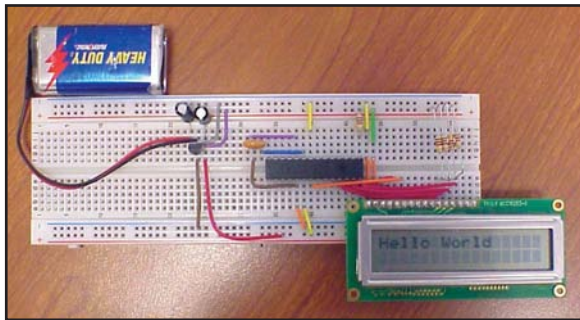
mentioned earlier, using the default connections gives us more code space. I'll probably use the defaults in future projects for that reason.

PROGRAMMING THE PIC

Now that we have written the program and successfully compiled and assembled it resulting in a binary LCD.hex file, the next step is to start up the PIC programmer software as seen in Figure 6. Make sure the software is set up to the proper COM port



⇒ FIGURE 6. PIC Programmer Software.



← FIGURE 7. Hardware Circuit With Programmed PIC.

Click yes and the PIC programmer LED will light indicating your PIC is being programmed. The software will display a message when the PIC is successfully programmed with your code.

and you've chosen the JDM programmer per the ICPROG directions. Install a blank PIC16F876A in the 28 pin socket and select that PIC in the software's PIC selection window. Also make sure the oscillator window shows XT mode and the LVP box is not selected in the fuses area. You're ready to load the file.

Load the LCD.hex file from where it was saved (usually in the PicBasic Pro directory). Press the "Program All" icon (the one with the lightning bolt) and the programming process will begin. ICPROG will ask you if you are sure you want to program this PIC.

RUN YOUR PROGRAM

After programming the PIC, remove it from the programmer and insert it into the breadboard and power up the circuit. The set-up I used is shown in Figure 7. When powered up, the LCD should show "Hello World."

NEXT STEPS

You have now learned how easy it is to program PICs in Basic and used some very low cost and free software

tools. From here, you can add a sensor to read temperature or light and display the value on the LCD. In fact, I'll do that in the next project article to demonstrate how to use Analog-to-Digital converters that are built into the PIC16F876A.

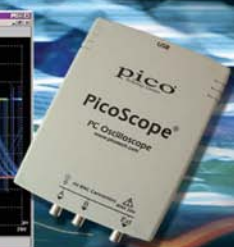
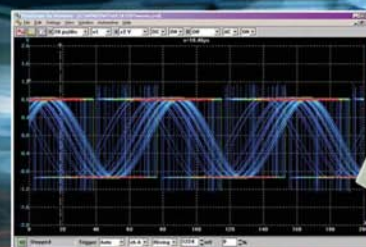
CONCLUSION

I hope I helped you learn to program PICs without fear of spending too much time or money. In future articles, I'll show how to interface the PIC to the outside world using these same tools and along the way, I'll introduce more. The world of PIC programming is so vast with new ideas arriving every day from some creative mind somewhere in the world. This just means I can probably write about this stuff forever. If you have a project idea you would like me to try and make with the PIC, shoot me an email at chuck@elproducts.com Maybe I'll make it the topic of one of my future articles. **NV**

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Oscilloscope timebases	5ns/div to 50ns/div	2ns/div to 50ns/div	1ns/div to 50ns/div
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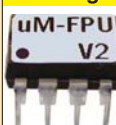
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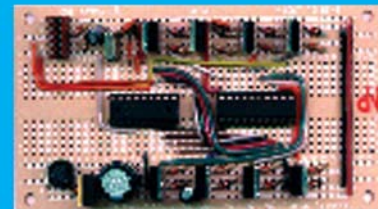
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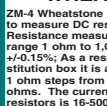
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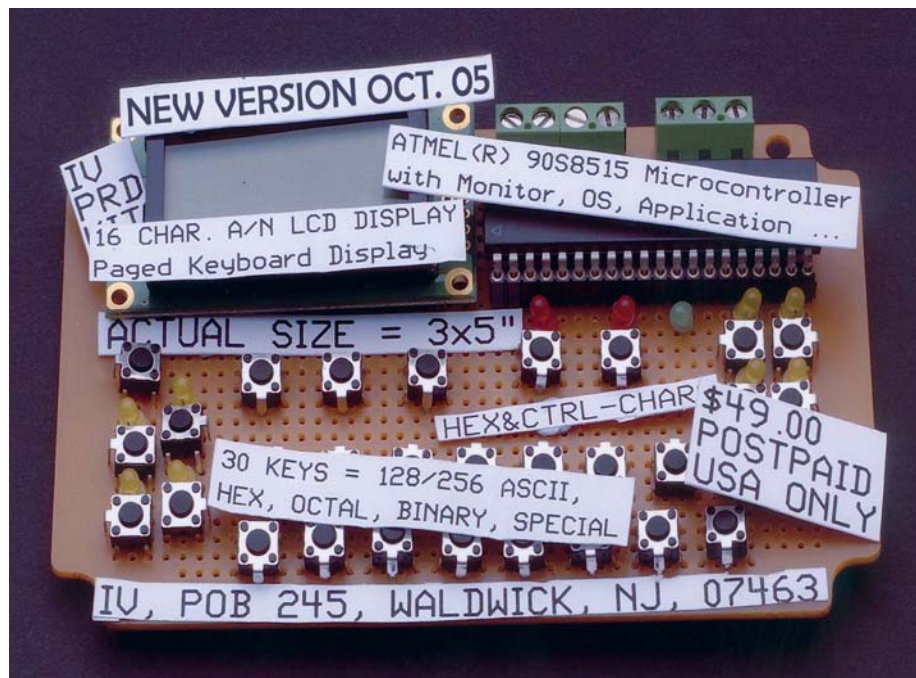
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■ BY L. PAUL VERHAGE

THE BLAME IT ON CanadArm*

AS YOU KNOW, THE SPACE SHUTTLE often carries an extraordinary robotic arm in its payload bay. The arm, called the CanadArm in recognition of its origin, is Canada's contribution to the Space Shuttle program. In my near space program, I often attempt to design near space versions of real space items. So, in recognition of the CanadArm, I have developed my version, the "Blame it on CanadArm." In this article, I'll describe how I constructed this arm.



The near space arm mounts to the exterior of the near spacecraft. Since it was design for amateur television use, the Blame it on CanadArm (BioCA) carries a small CCD imager at its tip rather than an end effector like the Space Shuttle's CanadArm. The BioCA is designed to point its CCD camera in any direction in front of the near spacecraft (the near spacecraft blocks the view behind it). The arm can point its camera to the ground, horizon, or the balloon itself. It can even monitor experiments during a near space mission.

It takes a flight computer onboard the near spacecraft to operate an arm like this. In my book (*Near Space Exploration With the BASIC Stamp*), if you'll read Chapter 3, you'll learn about the flight computer I'm currently using to control an arm like this. The first few chapters of my book are available as a free download from Parallax (www.parallax.com). Click on the Resources tab, then Customer Applications, then the Near Space

link in the list of customer applications. While you're there, check out the other near space applications Parallax has put online. Before constructing the BioCA, I want to give you a little information on amateur television.

A BRIEF BACKGROUND TO AMATEUR TELEVISION (ATV)

There are two kinds of amateur television in use today: fast scan and slow scan. Fast scan sends 24 frames per second and slow scan requires — depending on the transmission type — a few seconds to over 30 seconds to send a single frame. Fast and slow scan require a camera, radio transmitter, and antenna. However, slow scan also requires a microcontroller to capture a CCD image. The BioCA can be used for either type of television transmission.

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The antenna I recommend for ATV is the mini-wheel. The antenna is made by Dave Clinger of Olde Antenna Labs and you can order it from PC Electronics.

Your best source for up-to-date information on ATV is Gene Harlan's magazine, *ATV Quarterly*. You can find information for this magazine at www.hampubs.com

If you live near south central Idaho, you have a great source of ATV information in Lee Kelly (K6ZVA) in Twin Falls.

BACKGROUND ON MY AIRFRAMES AND QUAD PANELS

The BioCA is designed for my near space fleet. So let me briefly describe how I build an airframe. I build it out of 3/4 inch thick Styrofoam, the kind used for house

insulation. I cut Styrofoam panels with an Exacto knife and hot-glue them into a box. The box becomes an airframe after it's covered in multi-layer insulation and a fabric jacket. Three sides of the airframe have square openings where experiments are mounted. The openings are all the same size (a standard for my near space program) and are called access ports.

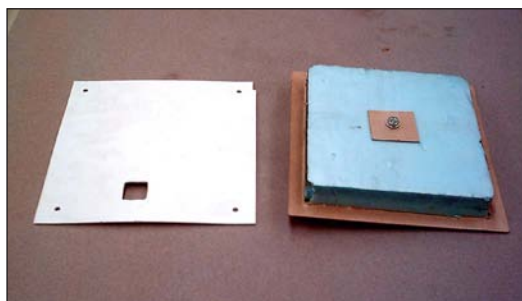
An experiment is bolted to an access port with a quad panel. A quad panel is a 3/4 inch thick Styrofoam square epoxied to a 1/8 inch thick plywood square plate. The Styrofoam square measures 5-1/4 inch on a side and fits snugly into an access port. The plywood square measures six inches across. While an experiment is permanently attached to a quad panel, the quad panels can be moved to any of the access ports in the airframe. In addition, since every one of my airframes has same size access ports cut into it, I can also move experiments between airframes.

A quad panel bolts to an access port with four bolts. The bolts pass through the inside corners of the Styrofoam square and to a thin plastic plate interior to the airframe. The quad panel remains on the airframe because the sides of the airframe are sandwiched between the quad panel and the interior plastic plate.

Using quad panels makes reconfiguring a near spacecraft a breeze. This brief description should be enough for you to construct a quad panel.

MAKING THE BIOCA

The BioCA is mounted to a quad panel just like any other experiment. The BioCA uses two standard 42 inch-ounce servos and one micro-servo to move its CCD camera around. The first servo is the yaw servo and it rotates the arm's base to the left and right. The second servo is the pitch servo and it raises and lowers the arm. The final servo is a micro-servo and it's the CCD



■ **FIGURE 2.** The Styrofoam measures 5-1/4 inches across and the plywood six inches across.

camera's pitch servo. It rotates the CCD imager left and right so it can view objects just beyond the BioCA's range.

To reduce the workload on the flight computer, a Scott Edwards SSC II controls the three servos in the arm. With the SSC-II, the flight computer can control the BioCA through a single I/O connection.

The weight of the camera combined with its distance from the servos places some torque on the servos. To keep the torque at a minimum and to reduce the drain on the battery, the rest of the arm is built to be lightweight. A large portion of the torque is counteracted with a rubber band. As you will see, the arm is constructed from Styrofoam for lightness and thin plywood for strength.

The quad panel is the first item to build. Cut a 5-1/4 inch by 5-1/4 inch square of 3/4 inch thick Styrofoam and a 6 x 6 inch square of 1/8 inch thick model plywood. Center and epoxy the Styrofoam to the plywood. Drill four 1/8 inch holes through the plywood at the corners of the Styrofoam. The Styrofoam side of the quad panel is the interior face and the plywood side is the side with the arm.

The yaw servo attaches to the quad panel with a shaped Styrofoam block. The top and bottom face of the block is covered in thin plywood for strength.

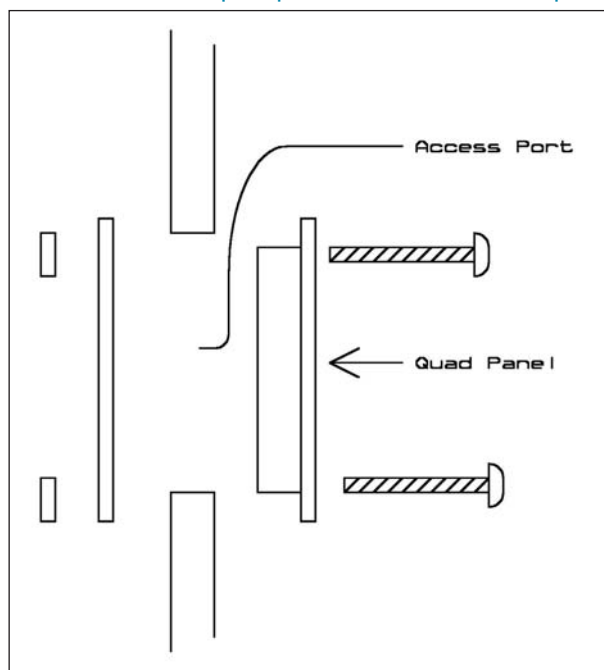


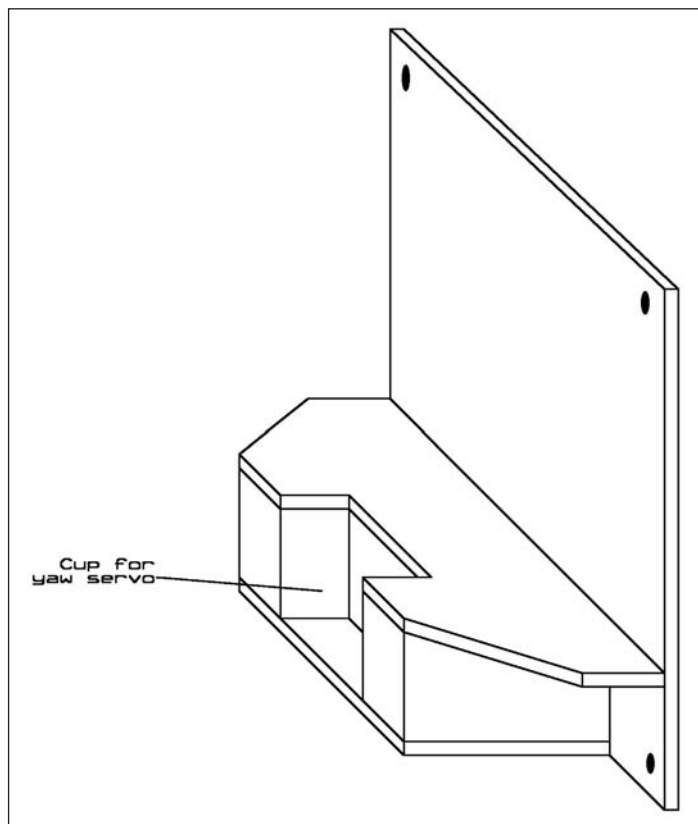
■ **FIGURE 1.** The access ports on this airframe measure 5-1/4 inches SQUARE.

The reinforced block is epoxied to the plywood face of the quad port. The servo slides into its pocket in the block and is held in place with two bolts. Figure 4 shows a diagram of the block I designed.

Now that the yaw servo is attached to the quad panel, we can attach the rest of the arm mechanism. The next piece is the rotation base. The rotation base holds the pitch servo, which raises and lowers (pitch- es) the arm. The rotation base is

■ **FIGURE 3.** An x-ray view of how a quad panel bolts to an access port.





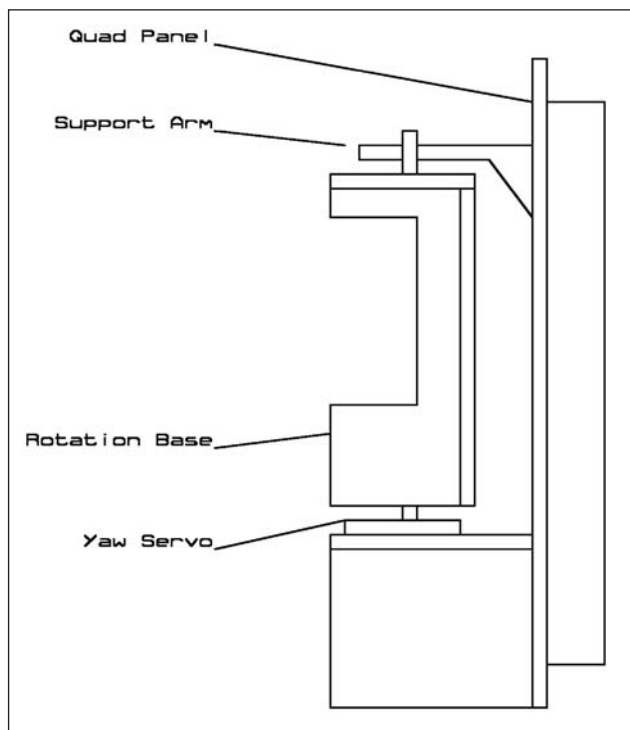
■ FIGURE 4. The shaped Styrofoam block for the yaw servo. In this diagram, it's already epoxied to the face of the quad panel.

pressed on to the rotation servo. When the rotation servo yaws left and right, it turns the rotation base and the arm attached to it.

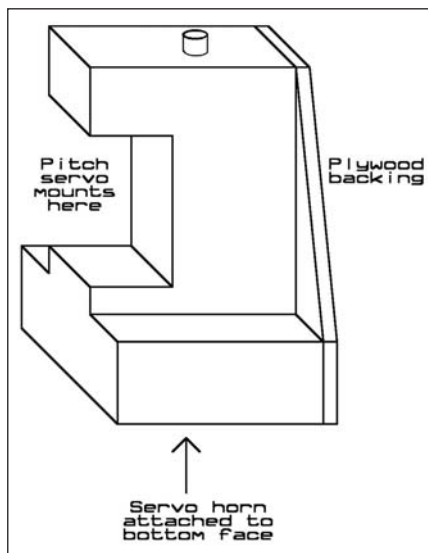
The rotation base is made from a

cut into the rotation base. Cutting a block out of the rotation base will weaken it structurally, so the opening is reinforced with 1/16 inch thick plywood. Not only does the reinforcement keep the rotation block from breaking where it was cut for the servo, but it's also a place to bolt the pitch servo.

A servo horn is bolted to the center of the bottom face of the rotation block. This is the servo horn that snaps into the rotation servo in the quad panel. A vertical axis runs through the rotation base. At its bottom is the center of the servo horn. The axis extends above the top of the rotation base where it creates



■ FIGURE 6. A side view of the quad panel and rotation base.



■ FIGURE 5. The rotation base looks like a horseshoe on its side and IS mounted to the wide base.

shaped block of Styrofoam and covered in thin plywood for strength. The pitch servo is bolted into an opening that's

servo horn on the bottom of the rotation block. Drill the hole about one inch deep. Cut a piece of dowel 1-1/2 inches long. Epoxy the dowel into the hole and let it set. You'll trim and round the top of the dowel after making its support bracket.

The support bracket bolts to the quad panel and holds the top axle of the rotation base.

The support bracket is made from 1/8 thick plywood and is basically a right angle bracket reinforced with more plywood. There are three holes in the support bracket: two to bolt the bracket to the quad panel and the other for the axle at the top of the rotation base. I drilled two 1/8 inch diameter holes for the #6-32 bolts that attach the support arm to the quad panel. The diameter of the hole for the axle is slightly larger than 1/8 inch so the axle in the top of the rotation base can spin inside of it without binding.

Now it's time to build the arm itself. The arm is made from 3/4 inch thick Styrofoam and laminated with thin plywood on its top and bottom surfaces. There's a servo horn attached to the base of the arm, a micro-servo to its mid-section, and the camera platform to its end.

The first step to making the arm is to cut the Styrofoam to shape. Notice in Figure 8, that there's a cutout in the arm large enough to

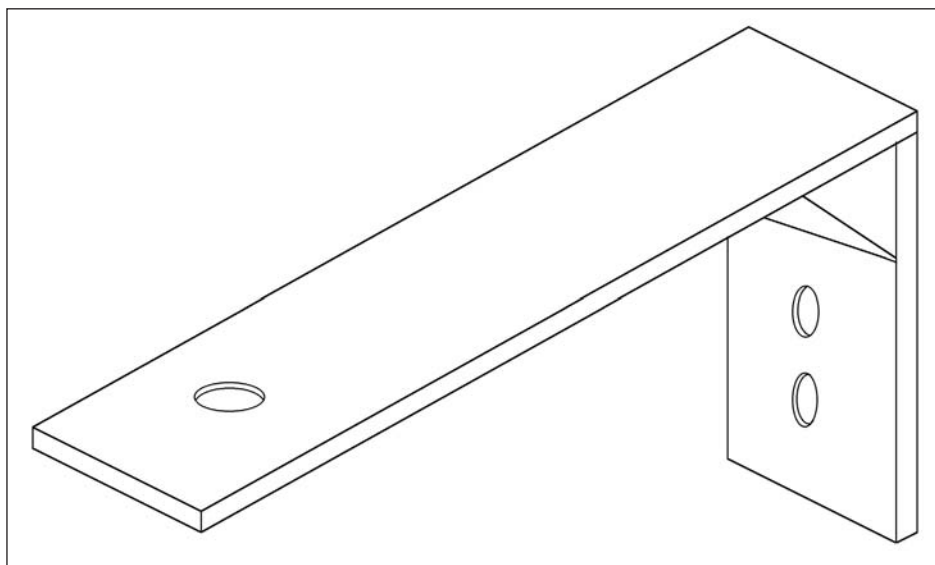
an axle at the top of the rotation base. The rotation block is kept from falling over by the rotation servo at the bottom and a bracket at the top.

The axle is a 1/8 inch diameter wooden dowel. Drill a 1/8 inch diameter hole through the top of the rotation base. Drill this carefully, as you want the dowel to be as centered and vertical as possible with respect to the

■ **FIGURE 7.** Your dimensions will vary, since your BioCA will probably not BE exactly the same size as mine.

hold a micro-servo. After cutting out the arm, laminate the 3/4 inch thick sides in thin plywood (use epoxy as the adhesive). For increased strength, use 1/16 inch thick plywood for this lamination. Next, epoxy 1/8 inch thick plywood panels to the sides of the arm that will cover the micro-servo cutout (there's no need to cover the entire sides of the arm in plywood since there's very little sideways force acting on it). The 1/8 inch thick plywood forms the sides of a pocket for the micro-servo. The plywood also strengthens the arm where the micro-servo cutout has weakened it.

Now mount a servo horn at the bottom of the arm for the pitch servo. Before the horn can be mounted to the arm, the end of the arm must be reinforced. Cover both sides of the arm where the servo horn will be attached with thin plywood. Use epoxy and 1/8 inch thick plywood. After the epoxy sets, hold the servo horn up against the plywood side and mark the location of the servo horn's center and the four outer holes in the horn's arms. Drill holes through the plywood reinforced arm at these locations. The center hole needs to be 1/4 inch in diameter, because the servo mounting screw goes through this hole. The holes in the ends of the servo horn arms are drilled for the mounting hardware you'll use to bolt the servo horn to the arm. I used small screws, but I recommend using something like #1 bolts and nuts.

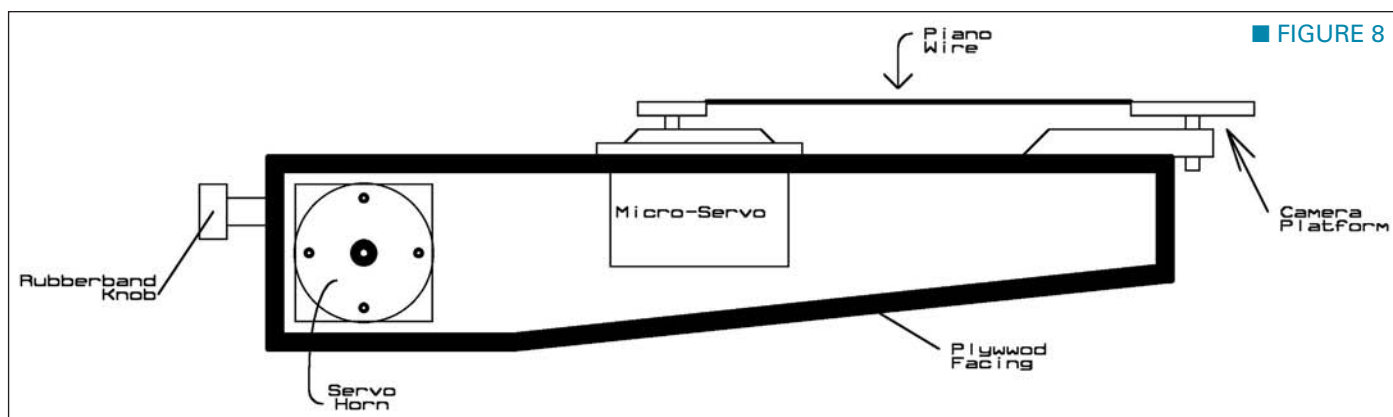


The weight of the CCD camera on the end of the arm means the pitch servo has a lot of torque to work against. This downward torque is counteracted by a rubber band pulling the arm up. The pull of the rubber band is not strong to lift the arm, it's just strong enough to counteract the arm's weight. A convenient way to attach the rubber band to the arm is with what I call the Rubber Band Knob.

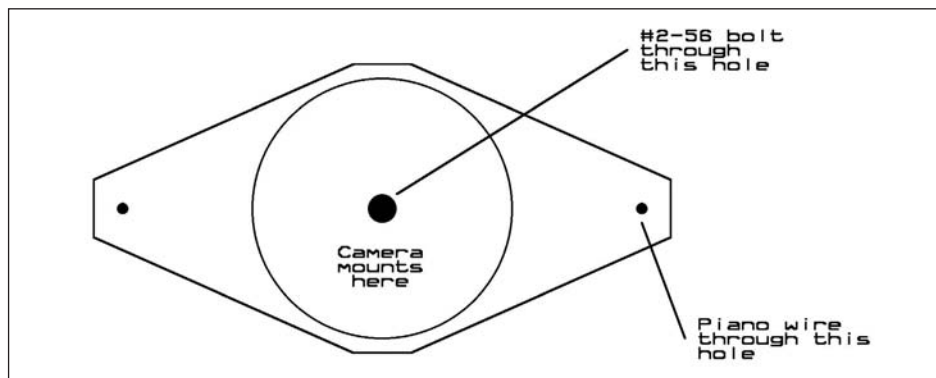
Drill a 3/16 inch diameter hole in the end of the arm. Make the hole about two inches deep. Then, cut a 3/16 inch diameter wooden dowel about three inches long. Epoxy and push the dowel into the hole until only one inch of the dowel protrudes. To keep the rubber band from slipping off, you'll epoxy a stop to the end of the dowel. Make the stop from a 1/4 inch thick stick of basswood. Cut a small square shaped piece of basswood. Find the center of the square

and drill a 3/16 inch diameter hole. Then, epoxy the square to the end of the dowel in the end of the arm. The rubber band that's pulling on the rubber band knob needs an anchor in the rotation base. I epoxied a short length of basswood strip to the rotation base for the anchor. With some additional plywood reinforcement on the rotation base, I believe a small eye hook could also be used as an anchor.

Next, add the camera platform and the platform shelf to the top of the arm. The platform is epoxied to the arm and the shelf is bolted to the shelf with a single bolt. The bolt is loose enough that the platform can rotate like a lazy Susan. Cut a 1-1/2 inch length of 1/4 inch by 3/4 inch basswood strip. Epoxy the shelf to the top end of the arm so that it extends about 1/2 inch beyond the end of the arm. After the epoxy sets, drill a 3/32 inch diameter hole through the shelf



■ **FIGURE 8**



■ **FIGURE 9.** A top view of my camera platform. The base of the tiny CCD imager mounts to the center of the platform.

at the center of its extension beyond the arm. A #2 bolt goes through this hole and acts as the axle for the lazy Susan platform for the camera.

The camera platform is made from a 1/16 inch thick sheet of hard modeling plywood. Do not use the light ply as it's likely to break from stress. Cut the platform large enough for your imager and two wing extensions.

Drill a small hole in each platform wing near the ends of the shelf. Piano wires from the micro-servo connect to these holes in the wings. So when the micro-servo rotates, the camera's lazy Susan platform also rotates.

Drill a 3/32 inch diameter hole through the platform's center. Push a

#2 bolt through the hole. Place washers on the bottom and push the bolt through the hole in the camera shelf. Use a locking nut (a nut with a nylon insert) to hold the lazy Susan to the shelf. Tighten the locking nut enough to take the slack out of the axle, but not so tight as to restrict its rotation. Attach the CCD imager to the lazy Susan according to the design of your imager. Be sure the lazy Susan can still rotate freely after the camera has been attached.

Now insert a micro-servo at the midpoint of the arm and screw it in place. I only used two screws (on diagonally opposite corners of the micro-servo) since there is very little force trying to lift the micro-servo out of its pocket in the arm.

Add a horn to the micro-servo and compare the width of the horn to the wings on the camera's lazy Susan. I added an extension to my servo horn to make it the same width as the

camera platform. In Figure 10, you can see that I used a strip of basswood for the servo horn extension. The horn's extension is held to the servo horn with epoxy and some wire, but you should use small bolts in place of the wires. Snap the servo horn (and its extension, if it was needed), to the micro-servo and rotate the servo to its mid position. Remove the servo horn and place it back onto the micro-servo and bolt it down.

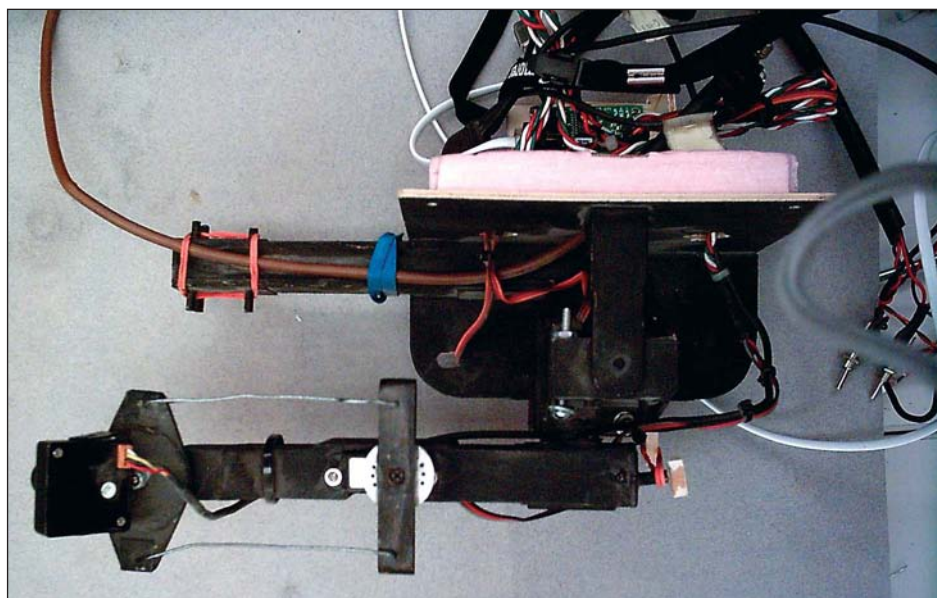
Measure the distance between the arms of the servo horn and the wings of the camera platform. Cut two pieces of stiff piano wire to the same length plus an additional inch. Insert the piano wires into the holes in the servo horn and camera platform and bend the ends over to keep them from falling out. Test the rotation of the camera platform by twisting the horn of the micro-servo. The camera platform must rotate without binding up. If all the servos rotate without binding, the exterior portion of the BioCA is complete.

Now bring the servo and camera wires inside the quad panel. I drilled two holes into the quad panel. I don't think you can get by with just one pass-through hole without the arm's rotation base binding up on wires. Since the SSC II is mounted inside the quad panel near the bottom, I drill my two holes about halfway up from the bottom of the quad panel.

After drilling the hole(s), epoxy a shelf inside of the quad panel that's large enough to hold the SSC II. I used 1/8 inch thick light ply for the shelf and used a bit of Styrofoam as a brace. After the epoxy sets, hold the SSC II in place and mark the location of its mounting hole in the shelf. Drill the holes and bolt SSC II to the shelf. I only used two of the mounting holes because there isn't much force trying to pull the SSC II off its shelf.

Pass the servo cables through the holes in the quad panel and connect them to the SSC II. You may have to extend the length of the cables to get them to reach. I extend servo cables

■ **FIGURE 10.** A top view of the arm. The rotation base is at the bottom, the micro-servo in the middle, and the camera platform at the top. Note the pair of piano wires connecting the extended arms of the micro-servo to the camera platform.



by cutting the servo cable in half near the middle and solder extension wires between the ends of the cut cable. Be sure to slide heat shrink on each wire before soldering it to the servo cable. After the servo cables, pass the camera cable into the quad panel.

Use wire zip ties to keep the cables under control. Without them, there's a possibility of a servo cable getting pinched and stopping arm movements. I tied cables to the mid point of the arm and left some cable slack near rotation points in the BioCA. To reduce the chances of video interference from servo signals, route the video cable away from servo cables. You don't want servo commands showing up as snow on the video signal.

The last item to make is the plastic panel that helps hold the quad panel to the access port. Cut a sheet of 0.03 inch thick styrene plastic into a six inch square. Drill four holes near its corners that correspond to the holes in the BioCA's quad panel. The holes for the servo and camera cables and the shelf for the SSC II will prevent a flush fit between the plastic panel and the quad panel. So cut a hole in the styrene panel just large enough for these protrusions. Now insert the quad panel into the airframe. Add the first bolt and add the plastic panel. Use a washer and nut to hold the quad panel and plastic panel in place. Repeat this with the other three holes.

Well, that does it for the BioCA. I've only had a chance to test it on the ground and display it in my presentation at a recent hamfest. The audience loved it. From my experience, I now see that it's important that the servo movements be slow and smooth. So, move the servos slowly by sending intermediate positions to the SSC II, rather than slamming servos to their new position. Also, use a lightweight CCD imager to keep the inertia of the arm low.

Onwards and Upwards,
Your new space guide **NV**

** No, I'm not a fan of the show, but
I do like the title of the song.*

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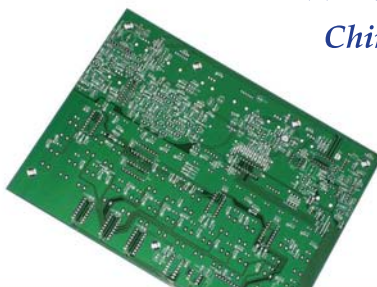
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IN THE TRENCHES

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THROUGH PRACTICAL DESIGN AND LESSONS LEARNED

■ BY GERARD FONTE

STRESS — OH NO!

IT'S CLEAR TO ANYONE IN THE ENGINEERING FIELD that stress is a part of the job. Whether it's making impossible deadlines, working long hours, finding invisible bugs, or interfacing with difficult people, engineering is a very high-stress profession. Coping with stress requires understanding what it is and what it does to you. Some stress you can control, some you can't. And there are some simple methods that can help you manage it.

WHAT STRESS IS

Sometimes stress is defined as that "overwhelming desire to pound the living daylights out of something." Unfortunately, stress isn't explained that easily. Stress certainly includes frustration and anger. But it's also present when you get married or divorced, get a new job or lose your present one, and even when you play video games. Sometimes stress is good. Sometimes it's physical and other times it's emotional. There are many different types and causes of stress.

The technical definition of stress is anything that causes the adrenal glands (located at the top of the kidneys) to release adrenaline (sometimes called epinephrine) into the blood stream. Now we can see why good things, like getting a new job or getting married, also cause stress. Excitement over something new causes

adrenaline to be released, too. This compound increases the heart rate and blood pressure while reducing "smooth muscle" activity (typically digestion). Basically, it's preparing the body for the "fight or flight" response.

In cave-man times, the fight or flight response was used with much more regularity than today. And the ability to battle harder or run faster was certainly helpful then. However nowadays, there are few fist-fights in the board-room and employees generally don't physically run away from a tough assignment. Fundamentally that's the basic problem of stress: the

body is ready for action but no action happens or is allowed to happen.

So, the adrenaline circulates and the heart rate increases and the blood pressure rises. And because there is no action,

the body remains in that state for an extended period of time. That's not good. It's like increasing the voltage to a motor in an emergency to get more power. It works, but the motor wasn't designed to run at the higher voltage or speed for long periods of time. It wears out faster.

Chronic stress (over four weeks) rarely has a direct effect on the body. Instead it aggravates existing conditions or lessens the body's ability to defend against other situations. Chronic stress can lead to stroke, heart-attack, kidney failure, stomach or intestinal ulcers, increased susceptibility to infections, headaches, fatigue, indigestion, and on and on. Truthfully, almost anything can be related to stress. Again, this is because the defenses of the body are reduced. This makes it easier for any component of the body to fail. And the weakest component varies from person to person and from time to time. Additionally, chronic stress engages a cortisol response. This has a number of subtle effects ranging from poor sleep to increased fat production to increased peripheral vision awareness. (This last effect can cause great difficulty in concentrating on things in front of you.)

Generally, there are three basic immediate and direct responses to very intense stress levels: head, heart, and gut. The head responders faint, the heart responders have palpitations or worse, and the gut responders need a new pair of pants. All



three types are well represented in movies or books. However, since these levels of stress rarely occur in normal engineering environments, we'll only look at the chronic stress that's more typical.

GOOD STRESS, BAD STRESS

There is one extremely good form of stress. It's called exercise. This is good since it burns up (simplistically stated) the adrenaline in your system. It's doing exactly what the body needs to do. And it is indeed stress. This is because as you start to work out, the adrenal glands release adrenaline and the heart beats faster and your blood pressure rises. The two special things about exercise are: the stress level is completely controlled by you and excess adrenaline, from other causes, can also be burned up. Doctors recommend exercise for everyone who is physically able. Obviously, exercise has many other healthful benefits, as well. The overall benefits of proper exercise are difficult to overstate.

It is critically important to recognize the control factor in stress. It's usually overlooked but it's often at the root of bad stress. Let's look at two people. The first one chooses to jog a mile during his lunch break for exercise. That's good stress. The second one is forced to do exactly the same thing because his boss needs a new stapler. Obviously, this isn't as good because anger and frustration are present to create stress. In fact, a classic study was done many years ago that demonstrated this directly.

This experiment used groups of paired monkeys. The first monkey of the pair was taught to perform a task and received a small electrical shock every time the task was performed improperly. The second monkey was separated from the first and was free to do whatever monkeys do. However, this second monkey also got shocked whenever the first monkey got shocked. Both monkeys got shocked exactly the same

amount. The big difference was that the first monkey could control the shocks through his behavior and the second one couldn't. The result was that the second monkey showed significant health problems. In short, the ability to control the stressful situation is very important in controlling the amount of stress.

PHYSICAL AND EMOTIONAL STRESS

We can see that some stress is the result of physical actions. Arguably, the most extreme form of physical stress is torture. However, the most likely forms of physical stress in the workplace come from overwork and lack of sleep. Pushing yourself beyond your typical capabilities requires the body to compensate. It does so by releasing adrenaline/cortisol to keep you awake and functioning. This is not too bad if it happens occasionally. However, it is bad if this is a chronic situation. It is also very important to remember that different people have different capabilities. Working 70-80 hours each and every week may be easy for Bob, but impossible for George. Simply because one person can accomplish this doesn't mean that you are less of a person if you can't. Additionally, management must recognize this, as well. It is fundamentally wrong and stupid to assume that everyone can perform to the maximum physical ability of the best person in the department. If that was truly the case, then Mr. Manager, you should easily polish off an Iron-man Triathlon every week.

Some people think "that which doesn't kill me makes me stronger." There certainly is some truth to this, but only under certain situations. One way to improve yourself is to push yourself beyond your limits.

Conquering adversity does give you confidence and experience. But chronic stress is more like the Chinese proverb, "running water wears away the strongest stone."

By far, the most common form of stress in the engineering arena is emotional stress. Most typically this comes from management's schedules. It seems that there is never enough time allotted to properly perform any task. The result is never-ending time pressure to design, debug, test, document, and manufacture a product. And, of course, once there is a problem in one facet of the system, the whole system is affected. We see that stress can be a communicable corporate disease.

The second common form of stress comes from working with "difficult" people. Perhaps you don't like your boss or he doesn't like you. Clearly, that makes the work environment stressful. Sometimes you have to work with someone who is annoying or has habits that you find distasteful. Other times you may be on a team where not everyone is doing his share. That means more work for you.

Lastly, you may be forced to do work that you dislike. Or more simply, you no longer like your job. It's true that many people have jobs that they don't like (although most engineers like their profession). The level of dissatisfaction is directly related to the amount of stress that occurs. It's important to realize that stress is a very personal condition. Each situation creates a particular stress level for each person. And this level is subjective. There is no easy way to measure how much stress any particular person is experiencing. Worse, the same stress level has different effects for different people.

COMPENSATION

There are many, many ways to

"Coping with stress requires understanding what it is and what it does to you. Some stress you can control, some you can't."

compensate for stress. You'll find dozens of books ranging from aerobics to Zen. All of them work for somebody. None of them work for everybody. Remember that stress is intensely personal. Additionally, certain compensation methods work better for certain types of stress. You will have to find what is best for you. The only way to find out is to try them and see what happens.

Anger and frustration are often purged with physical activity of some sort. One method that I have found very useful (and others who have tried it agree) is to hit golf balls. It's quick, easy, fairly inexpensive, and effective. Simply imagine the ball as being the stressor and hit it as hard as you can. After 50 or 100 whacks at the driving range, you will find most of the anger and frustration has dissipated. Pounding the living daylights out of something is very good at relieving anger and frustration.

You can try hitting baseballs in a batting cage. But that takes more skill

and concentration. You might also try racquetball or tennis. These are somewhat less effective and more complicated because you have to find a partner/opponent and locate a place to play. There are many other related ideas. Splitting firewood for example. But be very careful with the maul! Anger and frustration can make you careless.

One very effective technique is "totem-destruction." A friend had a boss who was, by all standard measures, not rational. Working for him was like doing a polka in a hammock — impossible and painful. However, a few years earlier he had given everyone in the department a large ceramic animal. We took this ceramic monstrosity and made a totem out of it. Adorned with rubber cement, spray paint, gobs of cat hair, and lighter fluid it was first set on fire (safely). Then the sledgehammer was employed. First into large pieces and then into smaller ones. The baseball bat whacked the

remains into a vacant field. The whole procedure took about two hours and was very cathartic. Later, at work, when the boss asked where the animal was, my friend just smiled and said, "It's found its proper place here and there around the house." (A new job eliminated that stressor for good.)

If you are stressed from overwork, a nap at lunch can be very helpful. Ideally, the nap should be away from the workplace, if practical. A quick bag-lunch and a 30 minute nap in your car can be effective. Car seats are much more comfortable than your desk chair and you aren't likely to be interrupted. Naturally, be careful where you nap. If you live close to where you work, a nap at home is very restful.

Exercise, as noted before, is extremely useful in reducing general stress. Jogging to lunch, instead of driving, works. Any exercise or energetic sport is beneficial. Lunchtime is good because it's always available

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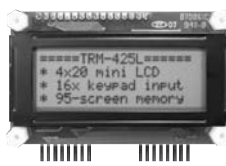
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(that's the law!). After work is better because you have more time. But it's often not practical because of other necessities. It's best to exercise away the stress while the stress is there. But, exercise is useful anytime.

Laughter is also a good method of reducing general stress. There is a Catch-22 here. The more stressed-out you are, the less funny humor is. And the less you laugh, the less reduction in stress there is. So when you get home, watch the Three Stooges rather than Engineering Disasters.

It should be noted that cigarettes, drugs, over-eating, and alcohol don't really do much to relieve stress. Rather, they cover it up. Worse, these things usually create additional physical stress.

SPECIAL CONSIDERATIONS

There is a common source of stress that is not yet qualified (to my knowledge). This is video games. It is clear that intense playing causes physical stress. The heart rate increases and blood pressure rises and there appears to be a release of adrenaline (however this last point has not been well-documented). The question is if this is good stress or bad stress. It appears to be good stress in that you have complete control over it. Like exercise, you decide when to start and stop. However, there is no physical activity associated with it to burn off the adrenaline. So, that would make it bad stress.

It seems to me that this would be a useful question to answer. There are many people who play video games for three or more hours per day. This is a major activity for them. Being at such a high level of stress for that long, day after day, would appear likely to have some impact on the body. But is it good or bad?

Bad dreams do not appear to be stressful. This suggestion is based upon observation rather than documentation. Simply, if you have a bad dream you wake up, roll over, and go back to sleep. This strongly suggests

that there is no release of adrenaline. Because if you had a load of adrenaline dumped into your system, the last thing you would want to do — or be able to do — is go to sleep. If you've ever been in a car accident, or other life-threatening event, you know the feeling.

CONCLUSION

Stress is a common factor in engi-

neering environments. But that doesn't make it good. Stress has been shown to contribute to many health issues. Reducing stress improves employee productivity and reduces absenteeism and turnover. The three basic methods for reducing stress are adaption, elimination, and compensation. Everybody's response to stress is different. Finding the proper methods that work for you is an important personal decision. **NV**

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- ④ Other Similar Topics

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>>> QUESTIONS

I have six six-volt batteries wired in series to achieve 36 volts. I have tapped the neg to the pos across two batteries and got 12 volts.

Can I wire all three (sets of two) and get 12 volts with lots of amps and run a large inverter? That would be running series and parallel in one operation. I would have to be using both sources at the same time. Maybe switches would work?

I had my hip replaced last week and am working on projects to complete after rehabilitation.

#1063 ■ Mark Mickelsen, via Internet

I have searched the world over for the Data Sheet on the TI's TMS9916NL chip. Any help would be appreciated.

#1062 ■ Brent Lamb, via Internet

I just got a digital caliper for the first time and I love it, mostly. I would like it to display measurements in a third way besides inches and millimeters. I would like to know if there are any digital calipers out there that have generic microcontrollers in them that could possibly be reprogrammed or replaced with one with my own programming in it. If they all have

custom chips in them, then I guess my idea is dead, but if one of them has something like a generic PIC in it, then maybe I could get something going. What can you tell me about them?

#1063 ■ Mark Mickelsen, via Internet

>>>> ANSWERS

[#11052 - November 2005]

I have a Proview Technology color-monitor model 986 N. To repair it, I need two ICs — TDA 9536 video amplifier and TDA 9210 video pre-amp. Does anyone know where I could get these chips at a reasonable price?

After an extensive search on the Internet I was able to locate the ICs that Mr. Eddy needs. If he goes to the site www.noahtec.com/xcart/customer/home.php?cat=253&page=11 he can order the two TDA ICs he needs; TDA9210 and TDA9536 both cost \$4.50 plus shipping and handling. Any questions he has he can e-mail the company directly.

The data sheets on the TDA9210 and TDA9356 can be found at the following websites:

www.romstore.ru/pdf/TDA9210.pdf
www.romstore.ru/pdf/TDA9536.pdf

■ Ralph J. Kurtz, Old Forge, PA

[#11053 - November 2005]

I'm trying to improve WWVB reception here in Southern New Hampshire. The problem seems to be that the internal antenna (tuned ferrite rod) in the clock can't be oriented properly where I want the clock located. I'm thinking along the lines of a larger, 0.5 X 7.5 inches, tuned ferrite rod feeding a FET op-amp, maybe an LF356. Drive a small audio transformer with the op-amp output to provide something like an eight ohm output to feed a twisted pair feedline. At the clock, use another transformer and connect it to an added winding on the original clock antenna rod. This would allow placing the antenna in correct orientation, as well as allow selection of a better antenna location. With the carrier at 60 kHz, it would seem that audio components could be used. I've checked the transformer — a

RadioShack 273-1380 (1K ohm to 8 ohm) — and it seems useful at 60 kHz. My question is, will something like this work, or is there something better? Thanks for any help or ideas.

Have you tried a few loose turns of wire around the ferrite rod and running the wires out at different angles? This method might capture and couple more field to your clock, and it's a lot simpler than a powered amp. Also check out www.selectantenna.com for ready-made signal boosters.

■ Bob Lindstrom, Broomfield, CO

[#12052 - December 2005]

I have some 4559 aircraft landing lights, they are 28 volt 600 watt. I was hoping to use them for some concert lighting I do. But, I haven't come up with a way to power them, being that I need a 28 volt 21.5 amp

power supply (I assume AC or DC will work).

I tried an off-the-shelf standard home dimmer, carefully setting it (low) to 12V-15V, but it just blew the bulb.

Sounds like you had a bad or old bulb. Running the 28 volt light is no different than running a 12 volt light on the old six volt tractors and cars; it should just be dimmer than at the full voltage, kind of like when the batteries are going dead in your flashlight. However, normally airplane landing lights are only used for a couple minutes during the landing. The bulb you have is a 600,000 candle power and the rated average life in the lab is only 25 hours. I think you should probably look for a better light. You also ask if AC or DC matters, this is a DC only bulb.

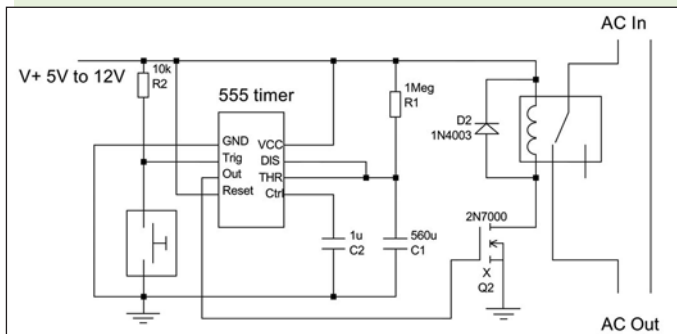
■ Dennis Matthews, Cameron, NC

[#11055 - November 2005]

I'm looking for a way to temporarily turn off an aquarium water pump during the feeding of my fish.

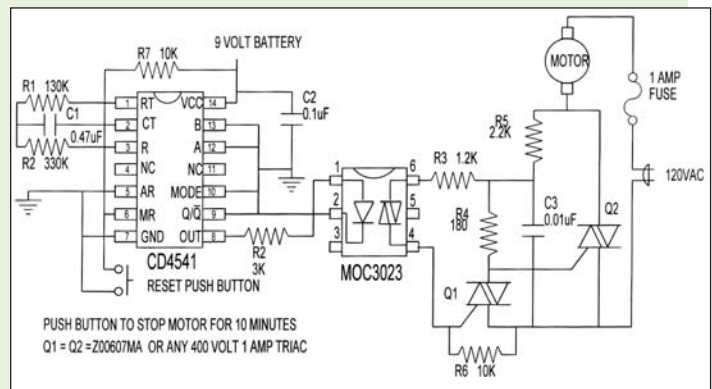
I need a circuit where the AC water pump (rated at 120VAC@40W) can turn off for about 10 minutes, then turn back on again automatically. Ideally, I'd like a momentary switch that would turn the pump off for about 10 minutes. I was thinking of using a relay with NC contacts and perhaps a battery-powered 555 circuit, but do not know how to design this.

#1 Here is a simple 555 timer circuit, that when you push the button, it will energize a relay for about 10 minutes. The timing formula is $T = 1.1 \times R1 \times C1$, so 600 seconds = $1.1 \times 1000000 \text{ ohms} \times .000554 \text{ farads}$ (554mfd). The 555 chip that I was working with has a supply voltage range of 5V to 16V, so a 12V wall wart would power it nicely. You will need a SPDT relay based on the voltage you pick. I think the schematic provided says the rest.



■ Brandon Spivey, Nashville, TN

#2 Ten minutes is a long, long time for a 555 timer, but a CD4541 programmable timer can do it easily. The schematic below shows how I think it would work but I have not built it, so there is no guarantee.



■ Russ Kincaid, Milford, NH

#3 To temporarily turn off an air pump or filter for an aquarium, an On-Delay relay such as Dayton 6X601 (60-900sec delay) or a 5B396 (36-3600sec delay) can be used. This is in an octal based package and so a base (part number 5X852) is needed to mount and connect the relay.

Place the pump and/or filter on the leads indicated "LOAD," and place a double pole momentary contact push button across the input (115V power source). When the relay is first powered up, the time delay period begins. When the time delay period is done, the relay allows the load to be powered up. The load remains



powered up until the input power is interrupted, at which point the delay period becomes active again. Load rating for the relay is 1/3HP @115V (seven amps) so it should be able to handle a number of devices such as a power head and a filter or air pump.

■ *Tom Pace*
S-S Electric Repair Shop
Buffalo, NY

#4 I had the same problem with my fishtank forgetting to reconnect the filter pump after feeding my fish. There are many solutions to remedy the problem, but the simplest I found is a delay on release timer from Amperite P/N 120ACR600C. Newark Electronics (800-4-Newark) can supply this timer. Only additional component needed is a momentary NO pushbutton switch.

■ *Frank Kretkowski, Jersey City, NJ*

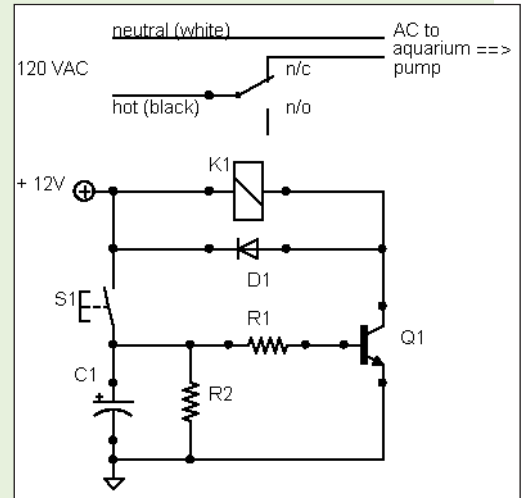
#5 May I suggest a universal start/stop timer kit made by Velleman Kits. It is available at MCM Electronics for \$15.95. www.mcmone.com/ part #80-2855. You can put the timer/relay in line of an inexpensive extension cord. The kit requires 12VDC which can be from batteries or a small wall transformer.

■ *Bob Lindstrom, Broomfield, CO*

#6 A very simple solution would use a low cost mechanical appliance timer. These are available at hardware stores for under \$10. Just set the "Off" time to midnight and the "On" time 15 minutes later. Whenever you feed the fish, spin the timer wheel around until the pump turns off. Fifteen minutes later, it will turn back on. If the fish are fed at least once a day, then the pump will never turn off by itself. But, if it should, it will not be a big deal since it will only be off for a few minutes.

■ *Thomas B., Folsom, CA*

#7 This circuit will interrupt the power to your aquarium pump for approximately 10 minutes. When you press S1, C1 charges very rapidly to +12 volts. The charge on C1 biases Q1 (an NPN Darlington) on and the relay is energized, interrupting power to the pump. The specified relay requires only 220 mW, well within the Q1 rating of 625 mW, and its contacts can handle up to eight amps. The relay will remain energized (keeping the pump off) until C1 discharges to about 1.2 volts, and the time taken depends primarily on the size of C1 and R2. You could use a one meg pot in place of R2 if you want the timing to be adjustable. Any 12 volt DC wall wart will power the circuit.



Parts List:

- C1 - 1000 uF 25V
- D1 - 1N4001
- K1 - Omron G6RN-1-DC12 (Mouser P/N 653-G6RN-1-DC12)
- Q1 - 2N6427 NPN Darlington (Mouser P/N 512-2N6427)
- R1 - 3.3 K
- R2 - 680 K
- S1 - Push button momentary switch

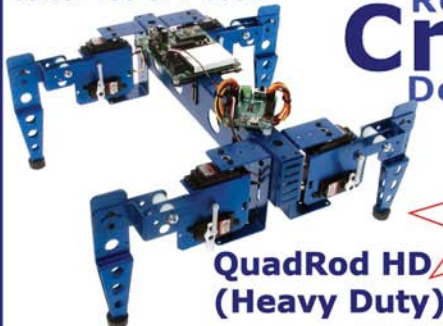
■ *Ed Schick, Harrison, NY*

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Details at Web Site > Test Equipment > Power Supplies



As Low As \$93.00!

High Capacity Nickel Metal Hydride Rechargeable Batteries

Item#

	1+	10+	100+
AA2500MAH "AA" cell 2500MAH	\$1.45	1.25	1.09
AAA850MAH "AAA" cell 850MAH	\$0.99	0.65	0.51
C3500MAH "C" cell 3500MAH	\$2.99	2.30	2.09
D11000MAH "D" cell 11000MAH	\$6.95	5.55	4.39
9V220MAH "9V" cell 220MAH	\$3.69	3.29	2.99

Details at Web Site

> Batteries & Accessories > NiMH Batteries

Triple Output Bench Power Supplies

with Large LCD Displays

Output: 0-30VDC x 2 @ 3 or 5 Amps
& 1ea. fixed output @ 5VDC@3A
Source Effect: $5 \times 10^{-4} = 2mV$
Load Effect: $5 \times 10^{-4} = 2mV$
Ripple Coefficient: $< 250uV$
Stepped Current: 30mA +/- 1mA
Input Voltage: 110VAC



CSI3003X3: 0-30VDCx2 @3A \$179.00 5+: \$169.00

CSI3005XIII: 0-30VDCx2 @5A \$219.00 5+: \$209.00

Details at Web Site > Test Equipment > Power Supplies

NEW!

Premier Repairing System w/Power Supply

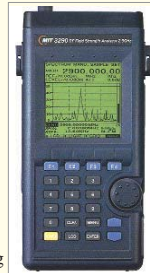
Microprocessor controlled design that provides stability and precision of temperature and airflow settings during the rework process. A full digital display of temperature and power source make everything clear to the user while the unit provides vast flexibility at the rework station with the built-in adjustable power supply that provides 0-15V and 2A of power. Hot air soldering and adjustment of temperature are controlled by a micro chip and sensor thus giving tremendous accuracy and reliability.

Item# **CS1768****Only \$289.00!**

- Iron Output Voltage: 24V / 35W
- Temperature Range: 100-480°C / 212-896°F
- DC Power Supply: 0-15V / 2A

[Details at Web Site](#) > [Soldering Equipment & Supplies](#)
2.9GHz RF Field Strength Analyzer

The **3290** is a high quality hand-held RF Field Strength Analyzer with wide band reception ranging from 100kHz to 2900MHz. The 3290 is a compact & lightweight portable analyzer & is a must for RF Technicians. Ideal for testing, installing & maintenance of Mobile Telephone Comm systems, Cellular Phones, Cordless phones, paging systems, cable & Satellite TV as well as antenna installations. May also be used to locate hidden cameras using RF transmissions.

Item# **3290**
[Details at Web Site](#) > [Test Equipment](#) > [RF Test Equipment](#)
Fantastic Low Price: \$1899.00!

- WFM/NFM/AM/SSB modulated signals may be measured.
- Signal Levels up to 160Channels can be displayed simultaneously on the LCD
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- LED Backlight LCD (192x192 dots)
- All functions are menu selected.
- RS232C with software for PC & printer interface
- Built-in speaker

(Includes Antenna)**B&W Pinhole Bullet Camera w/ 1/3" CCD**

- Weather Resistant Housing
- Signal System: EIA
- Image Sensor: 1/3" CCD Bullet Hole
- Effective Pixels: 510 x 492
- Horizontal Resolution: 380TV lines
- Min. Illumination: 1Lux/F1.2

Item# **VC-305CP**1-4: **\$49.00**5+: **\$46.00**
[Details at Web Site](#)
> [Miniature Cameras \(Board, Bullet, Mini's, B/W, Color\)](#)**4 Channel Digital Video Recorder w/250GB HD Installed**

- Signal System: NTSC
- Operation System: Embedded RTOS
- Video Input: BNC x 4
- Video Output: BNC x 1 / VCR OUT
- Resolution: NTSC 720x480/ NTSC 640x240
- Record Frame Rate: 30fps total
- HD Capacity: 250GB
- Backup: VCR
- Alarm In/Out: 4 in NO/NC, 1 Out No

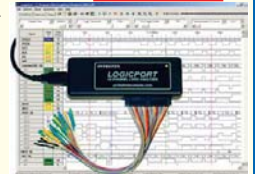
Item # **VR-214-200G****Only \$299.00****Special SALE!**
[Details at Web Site](#) > [Miniature Cameras \(Board, Bullet, Mini's, B/W, Color\) & Security](#)
Digital Storage Oscilloscope Module

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

[Details & Software Download at Web Site](#)
SALE!> [Test Equipment](#) > [Oscilloscopes/Outstanding Prices](#)Item# **200DSO** Only **\$829.00****LogicPort Logic Analyzer**

The LogicPort provides 34 sampled channels including two state-mode clock inputs. It connects to your PC's USB port for ultimate convenience and performance.

- 34 Channels
- 500MHz Timing mode sample rate
- 200MHz State mode sample rate
- Real-time Sample Compression
- Multi-level trigger
- +6V to -6V Adjustable Threshold

[Details at Web Site](#) > [Test Equipment](#) > [Logic Analyzers](#)
Item# **LOGICPORT****\$369.00!****Plug-In Switching Power Supplies**

These 15W switching power supplies are an inexpensive way to power devices with robust regulated power and low ripple noise. The low-profile design allow you insert them into a power strip without losing any of the other plugs. Designed with an energy efficient switching technology, the **Universal AC input works from 90-264VAC** with no minimum load required and a 100% burn-in test to ensure they will perform as stated right out of the box. They come with a 1.8 meter output cord and a 5.5 x 2.1mm female plug. UL and cUL approved.



Item#	Description
3A-161WU05	5 Volts / 2.6 Amps
3A-161WU06	6 Volts / 2.5 Amps
3A-161WU09	9 Volts / 1.70 Amps
3A-161WU12	12 Volts / 1.25 Amps
3A-161WU18	18 Volts / 0.84 Amps
3A-161WU24	24 Volts / 0.63 Amps

Each	10+	25+	100+
\$9.95	\$8.95	\$8.49	\$6.95

[Details at Web Site](#) > [Test Equipment](#) > [Power Supplies](#)
SONY Super HAD CCD Color Weatherproof IR Cameras

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

Item# **VC-827D** 1-4: **\$149.00** 5+: **\$139.00****SONY Super HAD CCD B/W Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# **VC-317D** 1-4: **\$69.00** 5+: **\$65.00****SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity****SONY Super HAD CCD Color Camera**

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

Item# **VC-805** 1-4: **\$69.00** 5+: **\$65.00**
[Details at Web Site](#)
> [Miniature Cameras \(Board, Bullet, Mini's, B/W, Color\)](#)**SONY Super HAD CCD Color Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# **VC-819D**
1-4: **\$89.00** 5+: **\$79.00****SONY Super HAD CCD Mini B/W Board Camera**

- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV Lines
- Min. Illumination: .05Lux/F1.2

Item# **VC-103** 1-4: **\$33.00** 5+: **\$29.00**

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Our popular *StampWorks* Manual has been revised and rewritten and is back better than ever! The *StampWorks* manual includes 35 experiments based on the BASIC Stamp® 2 microcontroller and the amazing Professional Development Board. *StampWorks* gives you the hardware, the electrical components and, most importantly, the know-how to become a confident embedded programmer. Working your way through *StampWorks* you will learn about efficient embedded design, connecting circuits and “smart” sensors to the BASIC Stamp, adding computer control to your projects, and “Power PBASIC” programming techniques.

After you’ve worked your way through *StampWorks* you’ll be able to: flash LEDs, use 7-segment and LCD displays, monitor one or several push-buttons or switches, add sounds and sound effects to your projects, build a simple light-controlled theremin, control servos and stepper motors, measure temperature, voltage, and so much more! When you are finished, you will be able to write your own BASIC Stamp programs to control your hobby, engineering, and student projects using a variety of electronic circuits – and you’ll be able to do it with the confidence.

\$249⁰⁰
EXCELLENT
VALUE!



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StampWorks EXPERIMENT KIT	27297	\$249.00
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